Technical Report 884

Human Factors Research in Aircrew Performance and Training: 1989 Annual Summary Report

D. Michael McAnulty, Editor
Anacapa Sciences, Inc.

March 1990

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for the Behavioral and Social Sciences

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)
This report presents summary descriptions of the research projects performed by Anacapa Sciences, Inc., for the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, under Contract No. MDA903-87-C-0523, entitled "Human Factors Research in Aircrew Performance and Training." From 9 October 1988 to 8 October 1989, Anacapa personnel worked on 31 research projects and 4 technical advisory services in emerging aviation weapon systems design, manpower and personnel programs, aviator training, and aviation safety research. The summary description for each project and technical advisory service contains a background section that describes the rationale for the project and specifies the research objectives; a research approach section that describes the tasks and activities required to meet the project objectives; a research findings section or, in the case of developmental activities, a research products section; and a project status section that describes projections for future research, if any.

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Technical Report 884

Human Factors Research in Aircrew Performance and Training: 1989 Annual Summary Report

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FOREWORD

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, contributes to the effectiveness of Army aviation by conducting a comprehensive human factors research program in support of aircrew performance and training. The ARIARDA research program encompasses the full scope of army aviation, with projects in support of emerging Army aviation weapon systems, aviation manpower and personnel programs, aviator training programs, and aviator safety programs.

This report summarizes research performed and products developed in all four of the above areas between 9 October 1988 and 8 October 1989 by Anacapa Sciences, Inc., under contract to the U.S. Army Research Institute for the Behavioral and Social Sciences. Thirty-one projects are summarized: 12 describe research in support of manpower and personnel programs; 13 report accomplishments in support of aviator training programs; and 1 describes research in aviation safety. In addition, four technical advisory services are described. The projects in emerging systems, aviation safety, and two technical advisory services are conducted within the mission of the Systems Research Laboratory at the Army Research Institute (ARI). The projects in manpower and personnel are conducted within the mission of the Manpower and Personnel Research Laboratory at ARI. Finally, the aviator training projects and two technical advisory services are conducted within the mission of the Training Research Laboratory at ARI. Specific taskings are identified for each project or research area, and the utilization of the research findings or products is described in each summary report.

This summary report is designed to meet two important objectives. First, it provides a summary of research progress and accomplishments to U.S. Army weapon system managers, manpower and personnel planners, and training system developers and managers in their respective areas of responsibility. Second, it provides summary information to behavioral scientists working on similar applied research issues, either in the Department of Defense or in other governmental, industrial, or university organizations.

EDGAR M. JOHNSON
Technical Director

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING: 1989 ANNUAL SUMMARY REPORT

EXECUTIVE SUMMARY

Requirement:

Anacapa Sciences, Inc., has provided collocated research support to the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, since 1981. The ARIARDA program supports the full range of Army aviation research requirements with projects that address issues in emerging aviation weapon systems, aviation manpower and personnel, aviator training, and aviation safety. This Annual Summary Report fulfills one of the requirements of Contract No. MDA903-87-C-0523. It describes the 31 research projects and 4 technical advisory services conducted by Anacapa Sciences, Inc., researchers between October 1988 and October 1989 in support of the ARIARDA program. The specific requirements that led to the initiation of each research project are discussed in the individual summaries.

Procedures:

There are substantial differences in the methods that were employed in the individual projects and in the technical advisory services. In some cases, the research approach was a scientific experiment in which selected variables were controlled, manipulated, and measured. In other cases, the research approach was a set of analytical or product development tasks. The specific research methods used in each project and technical advisory service are described in the individual summaries.

Summary of Contents:

The research projects were conducted in all four domains of the ARIARDA research program. Twelve of the projects are in the emerging aviation weapon systems domain. Ten of these projects address the prediction of operator workload in varying configurations of the LHX, AH-64, UH-60, MH-60K, CH-47, and MH-47E aircraft. The other two projects are concerned with the integration of maintenance considerations during the early design phases of new aircraft and the design of flight symbology.

Five of the projects are in the manpower and personnel research domain: an evaluation of the First Army Reserve aviation management method, the development and validation of a new aviator selection test (two projects), the development of a peer assessment method, and a survey of aviation ammunition and gunnery training practices and requirements. Thirteen projects are part of the aviator training research domain. Six of these projects are concerned with the evaluation of flight simulator training; the other seven projects are concerned with developing an AH-64 symbology training program, upgrading the basic map interpretation and terrain analysis course to videodisc, surveying the research on computer-based instruction, and conducting four evaluations of the effectiveness of aviation part-task trainers. Finally, one project was initiated during the current contract year to develop and evaluate simulated accident scenario training as a method of improving aviation safety.

The four technical advisory services were concerned with participating in the Special Operations Aircraft Program in-progress reviews and crew station working group meetings, supporting research in operator workload measurement, developing software for a flightline research system, and developing and evaluating a computer-based threat training program.

Utilization of Findings:

The results and recommendations of many of the projects and technical advisory services will be directly implemented in the design of new aviation systems, in the selection and management of aviation personnel, and in aviation training at the Aviation Center, Fort Rucker, Alabama, and in Army aviation units around the world. This report provides Army weapon systems managers, manpower and personnel planners, training system developers and managers, and other researchers working in related fields with a summary of the research activities in their respective areas of interest.

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING: 1989 ANNUAL SUMMARY REPORT

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AA	Active Army
AAA	Army Audit Agency
AAWWS	Airborne Adverse Weather Weapon System
ADTA	Aviation Development Test Activity
AO	Aeroscout Observer
AQC	Aircraft Qualification Course
ARIARDA	Army Research Institute Aviation Research and Development Activity
ARMS	Aviation Resource Management Survey
ARNG	Army National Guard
ARTEP/MTP	Army Training and Evaluation Program/Mission Training Plan
ASMIS	Army Safety Management Information System
ATB	Apache Training Brigade
ATHS	Airborne Target Handover System
ATM	Aircrew Training Manual
AVCATT	Aviation Combined Arms Tactical Trainer
AVG	Final Academic Average
AVNOAC	Aviation Officer Advanced Course
AVSCOM	Aviation Systems Command
CBAC	Cavalry Brigade - Air Combat
CBI	Computer-Based Instruction
CBMS	Computer-Based Memorization System
CMS	Combat Mission Simulator
CO	Commissioned Officer
CONUSA	Continental United States Army
CPG	Copilot/Gunner
CSRDF	Crew Station Research and Development Facility
CSWG	Crew Station Working Group
CWEPT	Cockpit, Weapons, and Emergency Procedures Trainer
DA	Department of the Army
DARPA	Defense Advanced Research Projects Agency
DCST	Deputy Chief of Staff for Training
DGFS	Department of Gunnery and Flight Systems
DOTD	Directorate of Training and Doctrine
EEA	Essential Elements of Analysis
EGA	Enhanced Graphics Adapter
EIDS	Electronic Information Delivery System
ETM	Emergency Touchdown Maneuver
FAR	Faculty Advisor Rating
FAST	Flight Aptitude Selection Test
FLIR	Forward-Looking Infrared
FLRS	Flightline Research System
FORSCOM	Forces Command
FRED	Fully Reconfigurable Experimental Device
FWS	Flight and Weapons Simulator
FY	Fiscal Year
HMD	Helmet-Mounted Display

GLOSSARY OF ACRONYMS AND ABBREVIATIONS (Continued)

IAS	Integrated Avionics Subsystem
ICS	Interphone Control System
IERW	Initial Entry Rotary Wing
IHADSS	Integrated Helmet and Display Sighting System
IP	Instructor Pilot
IVD	Interactive Videodisc
LHX	Light Helicopter Family
LOS	Line of Sight
LZ	Landing Zone
MANPRINT	Manpower and Personnel Integration
MAPPS	Maintenance Personnel Performance Simulation
MFD	Multifunction Display
MITAC	Map Interpretation and Terrain Analysis Course
NBC	Nuclear, Biological, and Chemical
NFAST	New Flight Aptitude Selection Test
NG	National Guard
NOE	Nap of the Earth
NVD	Night Vision Device
OAG	Overall Average Grade
OWL	Operator Workload
PC	Peer Comparison
PM	Program Manager
PNVS	Pilot Night Vision System
RAM	Reliability, Availability, and Maintainability
RC	Reserve Component
RFAST	Revised Flight Aptitude Selection Test
SFTS	Synthetic Flight Training System
SIMNET	Simulation Networking
SME	Subject Matter Expert
SOA	Special Operations Aircraft
STRAC	Standards in Training Commission
TADS	Target Acquisition and Detection System
TAWL	Task Analysis/Workload
TEA	Training Effectiveness Analysis
TOSS	TAWL Operator Simulation System
TRADOC	Training and Doctrine Command
TSTT	Target Acquisition and Detection System Selected Task Trainer
USAAVNC	United States Army Aviation Center
USAR	United States Army Reserve
USAREUR	United States Army, Europe
USASC	U.S. Army Safety Center
VAX	MicroVax II Microcomputer
WOC	Warrant Officer Candidate

HUMAN FACTORS RESEARCH IN AIRCREW PERFORMANCE AND TRAINING: 1989 ANNUAL SUMMARY REPORT

Introduction

Anacapa Sciences, Inc., has provided collocated research support to the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) at Fort Rucker, Alabama, under a series of contracts that began 1 September 1981. The current contract (No. MDA903-87-C-0523) requires the submission of an Annual Summary Report of research project activities. This report describes the Anacapa research project activities and achievements during the period from 9 October 1988 to 8 October 1989. Throughout the report, this period is referred to as the current contract year.

Ten of the research summaries in this report describe individual projects that Anacapa Sciences personnel have worked on during the current contract year. Eight of the summaries describe major, long-term research areas that are divided into 21 discrete projects; each project will conclude with a deliverable product. The projects are listed in the table of contents under the title of the research area. Finally, four summaries describe technical advisory services, which are research activities or expert assistance provided to Army programs and projects that are not directly assigned to Anacapa Sciences.

Most of the project and technical advisory service summaries follow the same general format. Each summary begins with a background section that presents information needed to understand the requirement for the project. The background may include a brief review of the relevant research literature or describe the critical events that led to the initiation of the project or technical advisory service. Where appropriate, the relationship between specific projects in a research area or between an Anacapa research project and a technical advisory service is discussed.

When the need for the research cannot be clearly inferred from the background information, a statement of need or definition of the research problem is presented. This is followed by a concise statement of the project or research area objectives. Next, the research approach section presents a description of the activities that were planned to accomplish the research objectives. For some projects, the research approach is a scientific experiment in which selected variables are controlled, manipulated, and measured.

For other projects, the research approach is a set of analytical or product development tasks.

The research approach is usually followed by one or more sections that describe the work completed on the project and research findings or, in the case of product development efforts, a summary description of the research products. In the technical advisory service summaries, the research approach is usually followed by a description of the services provided by Anacapa personnel. The final section of each summary describes the work projected, if any. Where possible, this section also presents the current project milestones.

Anacapa personnel also provided temporary research, technical, administrative, and logistical support on other projects that are the primary responsibility of ARIARDA personnel and are, consequently, not summarized in this report. It is important to note that the projects summarized in this report represent only a portion of ARIARDA's research program. Numerous other projects are being conducted either in-house by ARIARDA personnel or under other contracts.

The project summaries are presented in four content categories that reflect the research domains at ARIARDA. This organization is intended to assist the reader in locating a specific project summary within a research domain or in finding summaries that are closely related in terms of content.

The first six summaries describe 12 projects in emerging aviation systems design. The next four summaries describe 5 projects in manpower and personnel research. The next seven summaries describe 13 aviator training research projects. The last summary describes a new project designed to develop and evaluate simulated accident scenario training as a method of increasing aviator safety. The number of projects assigned to the four categories is not necessarily in proportion to the emphasis placed on each research domain.

The project summaries are followed by descriptions of the four technical advisory services. Technical advisory services were provided to support (a) aviation system research and development programs being managed by Aviation Systems Command managers and engineers and (b) aviation projects being conducted by ARIARDA scientists. The first two summaries describe technical advisory services provided in support of emerging aviation systems design. The third summary describes support provided in the development of a flightline research data management system. The fourth summary describes a technical advisory service provided in support of an ARIARDA training research project.

Although each summary identifies the project director or technical advisor(s), the Anacapa approach to research employs a team concept. This approach provides the optimum utilization of each scientific staff member's skills and ensures coordination among closely related projects. The scientific staff members are supported by an exceptionally efficient administrative and technical staff. All of the research effort is closely coordinated with ARIARDA personnel.

DEVELOPMENT OF A TASK ANALYSIS/WORKLOAD
OPERATOR SIMULATION SYSTEM (TOSS)

Ms. Laura A. Fulford, Project Director

Background

Anacapa Sciences researchers, under contract to the Army Research Institute Aviation Research and Development Activity (ARIARDA), Fort Rucker, Alabama, developed a task analysis/ workload (TAWL) methodology for predicting operator workload during the conceptual phase of new system development. The methodology was first applied to the Army's Light Helicopter Family (LHX) aircraft (McCracken & Aldrich, 1984; Aldrich, Craddock, & McCracken, 1984; Aldrich, Szabo, & Craddock, 1986).

Subsequently, Anacapa personnel refined the mission/ task/workload analysis methodology and produced operator workload prediction models for the AH-64A (Szabo & Bierbaum, 1986), the UH-60 (Bierbaum, Szabo, & Aldrich, 1989), and the CH-47 aircraft (Bierbaum & Aldrich, 1989). Each of the original workload prediction models was programmed in FORTRAN 77 on a Perkin-Elmer 3210.

Need

The FORTRAN 77 programs for the LHX, AH-64A, and UH-60 workload prediction models incorporate the model decision rules into the actual program code. Time-consuming recompilations of the programs are required to incorporate even minor changes in the models. A TAWL operator simulation system (TOSS) is required that reduces the development time for implementing changes to existing models or creating new models.

Research Objective

The primary objective of this project is to develop a software system that (a) can incorporate model changes without rewriting and recompiling the software and (b) is powerful and flexible enough to exercise any of the workload prediction models developed with the refined TAWL methodology. In addition, the software system should be easy to use, portable, and easy to modify for the development of new workload prediction models.

TOSS Design

The TOSS software uses data files to store all model information peculiar to a specific aircraft. This design approach enables the programmer:

- to change an existing model's execution by changing its data files, thereby eliminating the need to rewrite and recompile the program to incorporate the changes, and
- to implement new computer models developed with the refined methodology merely by creating a new set of data files.

Although the technique of using data files to store all model information resolved the primary problems described above, the data entry of model information using an editor is time consuming and subject to errors. A data base management system with specialized routines was designed for entering and updating all of the data used in the workload prediction models. Each specialized routine features customized error checks to help ensure the validity of the data files. The most critical data files are protected by automatic backup procedures.

A simple and consistent user-interface was developed to produce a system that is easy to use. The software system was developed for use on the IBM AT compatible computer to meet the objective of portability. Turbo Pascal was selected as the development language to meet the objective of easy modification.

TOSS Modifications

During the current contract year, numerous modifications were made to improve the basic TOSS software. First, a directory utility was developed to provide the following system capabilities:

- the capability to build and work with a data base in any directory (earlier versions were limited to the root directory or a first-level directory);
- the capability to add, delete, and rename directories; and
- the capability to rename, copy, and move files.

Second, the workload prediction model was upgraded so that it can process 11 random functions per segment decision rule rather than the previous maximum of 8. In addition, a new set of data structures was developed that utilize pointers rather than arrays for the model execution routine. The new structures use less computer memory and store data more efficiently than the array structures. The data base management system was also upgraded to manage 700 tasks rather than the previous maximum of 689.

Third, a menu of output options was added to the model execution routine. The menu allows a user to execute a model and produce (a) no output, (b) a simulation listing, (c) an abbreviated simulation listing, (d) data files of operator workload totals, or (e) a listing of the tasks performed within the segment.

TOSS 3.0

At the request of ARIARDA, TOSS was upgraded to a version 3.0. Version 3.0 was designed to accommodate up to four crewmembers in one model rather than the previous maximum of two crewmembers. A more consistent user interface was developed for TOSS 3.0. With the previous data entry routines, different responses were required to complete different entries. In version 3.0, a user must press the "Enter" key to complete a response in every situation except for menu prompts and questions that require a "Y" or "N" answer. Furthermore, the scales in the workload data file were converted from character data to real numbers ranging from 0.0 to 99.99. Finally, a conversion program (Convert3) was created to allow users to convert their previous data files to the version 3.0 format.

In May 1989, TOSS version 3.0, Convert3, a draft copy of the guide for using TOSS, and an archived copy of the source code were delivered to ARIARDA for distribution.

TOSS 3.1

During the remainder of the contract year, further modifications were made to upgrade TOSS to version 3.1. Version 3.1 makes it possible to compare workload between different aircraft. In earlier versions, random functions were executed at random times during the segment, and the number of times the functions were executed was random. Direct comparison of the same mission segment for different aircraft was impossible unless the random functions happened to be executed the same number of times in each model. In TOSS 3.1, an option in the system parameters section allows the analyst to set the number of times that random functions and tasks are executed.

Four changes were made to the output options in TOSS 3.1. First, a user can send a detailed listing of the data to a text file that can be either viewed on the computer screen or printed. Second, the output from the task, function, or segment names can be printed numerically or alphabetically.

Third, version 3.1 of TOSS allows for the selection of multiple options in one execution of the model. In version 3.0 of TOSS, the model had to be performed separately for each needed option. Fourth, the standard output files include basic statistics (e.g., mean, standard deviation) that are computed for each workload component for each crewmember during each segment.

Three modifications were made to the data base management system in version 3.1. First, the user is able to indicate that a segment is to end after a specific function is performed. Second, version 3.1 models the discrete random tasks independently. This software modification allows the crewmember and the probability of occurrence to be specified for each of the discrete random tasks in a function rather than for a set of random tasks. Third, the maximum number of tasks was increased from 700 to 800 and the maximum number of interrupts was increased from 10 to 11.

Finally, changes were made in the esthetics of TOSS version 3.1. Version 3.1 uses color, shadow-box, and windowing routines throughout the application. To maximize visibility on different computer monitors, the user has the option of executing the programs using either a color or a monochrome monitor.

Ancillary Programs

Five ancillary programs and procedures were developed to support version 3.1. First, an update program (Update31) was developed to allow users of TOSS version 3.0 to convert their data files to the version 3.1 format.

Second, three workload graphing programs were created. The first program graphs operator workload totals that are produced during the execution of a TOSS model. The second program produces a bar chart to compare the average workload for each crewmember in two different models. The third graphing program produces a bar chart to compare the average workload in a segment for two crewmembers in the same model.

Finally, a program that contains three utility procedures was developed for TOSS 3.1. One utility procedure lists all the functions that contain a particular task. A similar utility procedure lists all the segments that contain a particular function. The third utility procedure converts the ordinal workload scales to interval scales in the AH-64A model.

User's Guide

Between February and October 1989, the draft guide for using version 3.0 of TOSS was edited and revised. The guide is divided into two major sections. Part I is an overview of the TAWL methodology and describes the three major stages required to develop a workload prediction model: a task/workload analysis, the construction of the model, and the execution and debugging of the model. This section provides managers with sufficient information to decide if TAWL/TOSS is an appropriate analytical tool for analyzing workload on a particular system.

Part II is a step-by-step guide for using TOSS. The guide is structured to parallel the hierarchical set of program command menus. For example, each of the six selections present on the main menu of the program is represented as a section in Part II.

Parts I and II are supplemented by a glossary and three appendixes that provide examples of workload rating scales, model data bases, and model outputs.

Work Projected

The revised guide for using TOSS version 3.0 will be submitted to ARIARDA in October 1989. TOSS version 3.1 will be completed, tested, and distributed, along with the update program, utility program, and an updated copy (version 3.1) of the guide.

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THE AH-64 WORKLOAD PREDICTION MODEL

Dr. David B. Hamilton, Project Director

Background

The Army's Air/Land Battle 2000 scenario presents a high-threat environment that will place heavy workload demands on combat helicopter operators. To increase mission effectiveness in this environment, the latest Army helicopters have been equipped with advanced technology. This technology includes electronic sensor capabilities that increase both the amount and fidelity of information available to the operators.

The AH-64A Apache attack helicopter is equipped with the most advanced technology of any helicopter currently in the U.S. Army inventory. It is the first Army aircraft equipped with flight and weapon systems that allow missions to be conducted at night and under adverse weather conditions. The increased mission capabilities of the AH-64A aircraft have dramatically increased the amount of information that the operators must process. The AH-64A Apache is equipped with automated flight and combat (acquisition, targeting, and engagement) technology that is intended to reduce crew workload. In some instances, however, the tasks required to use the technology have either increased workload or simply changed the nature of the task without decreasing workload. High workload, in turn, reduces mission effectiveness, increases system manning requirements, and increases the training necessary for acquiring and maintaining flight proficiency.

One reason that technology has failed to reduce operator workload in Army aircraft is that human factors concepts were not adequately considered during the early stages of system design. For example, many of the subsystems in the AH-64A were not integrated to simplify the man-machine interface and reduce the operator workload in the cockpit. In the past, no methodology existed for assessing the workload demands of emerging aviation/weapon systems prior to their development. However, researchers from the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) and Anacapa Sciences have developed a methodology for predicting the workload demands placed on the crewmembers by the advanced technology proposed for the light helicopter family (LHX) aircraft.

Recently, Anacapa researchers have refined the LHX methodology to support its application in evaluating operator workload in existing or developmental weapon systems; the refined methodology is called the Task Analysis/Workload (TAWL) methodology (see Bierbaum, Fulford, & Hamilton, 1989). In addition, computer support for the methodology has been developed and named the TAWL Operator Simulation System (TOSS).

The methodology takes a multidimensional view of human capabilities that enables the system engineer to identify modifications that shift operator workload from one domain to another. For example, technology that reduces an aviator's need to maintain physical control of system functions often increases the aviator's role as a monitor. Thus, advanced technology may decrease operators' psychomotor workload and increase their cognitive workload. Because of the limited capacity of human cognitive ability, system designers must avoid shifting all the workload associated with aircraft operations into the cognitive domain (or into any other single domain). The TAWL methodology, with its second-by-second estimate of operator workload, allows the system engineer to utilize all the operators' capabilities better and, consequently, increase system effectiveness.

The Army is currently developing an improved AH-64 helicopter called the Longbow Apache. The man-machine interface will change substantially with the incorporation of two touch-screen multifunction displays and the removal of the majority of the switches and dials. The major additions in the Longbow Apache will be the Airborne Target Handover System (ATHS), an Integrated Avionics package, and the Airborne Adverse Weather Weapon System (AAWWS).

Need

The Aviation Systems Command (AVSCOM) requested that ARIARDA apply the TAWL methodology to evaluate the operator workload in the AH-64A Apache and in the Longbow Apache currently being developed. In response to AVSCOM's request for support, ARIARDA tasked Anacapa to conduct the required research.

Research Objectives

The overall objective of the AH-64 workload prediction research is to determine the effect that advanced technology is likely to have on the workload of AH-64 attack helicopter crewmembers. The research is divided into the following three specific objectives:

- determine the operator workload for the current configuration of the AH-64A aircraft,
- predict the effect that Longbow design modifications will have on crew workload, and
- identify the AH-64 mission functions and subsystems for which design modifications will be most beneficial in reducing crew workload.

The workload predictions yielded by the research will estimate the crewmember workload in the AH-64A and Longbow Apache and provide a workload criterion for evaluating the development of the helicopter.

Research Approach

The research for meeting these objectives is divided into three projects:

- development of a model to predict AH-64A crewmember workload,
- validation of the AH-64A workload prediction model and the TAWL methodology, and
- assessment of the workload effects of Longbow Apache design changes.

Each of the projects is described more fully below, following a brief description of the work completed under a former contract.

Previous Research

Szabo and Bierbaum (1986) conducted a task/workload analysis of all phases of the AH-64A attack mission. A composite mission scenario was developed from five mission profiles that assumed optimal flight conditions. In the composite scenario, the pilot's primary function is to fly the aircraft, and the gunner's primary function is to acquire and engage targets. No reconnaissance or team leader functions are performed by the crew. Seven mission phases were identified and divided into 52 unique mission segments. The segments were further divided into 159 unique functions with 688 individual tasks necessary to the mission. Finally, the subsystem, crewmember, and duration for each task was identified.

Development of the AH-64 Workload Prediction Model

The development of a computer model to predict workload for the AH-64A Apache crewmembers will be divided into four tasks. The initial task will be to enter the mission/task/workload analysis data into a computer data base. The second task will be to develop and enter the function and segment decision rules into the computer. A function summary sheet will be developed for each unique function to identify the specific tasks performed by each crewmember. Function decision rules will be written using the function summary sheets. Function decision rules specify the sequence and time for performing the tasks. Following the development of the function decision rules, segment summary sheets and decision rules will be developed. The segment decision rules specify the sequence and time for performing the functions in each mission segment.

In the third task, the TOSS software will be utilized to automate the analysis of workload. The computer program will use the function and segment decision rules to combine the tasks to form functions which, in turn, will be combined to form segments. The computer program will simulate the sequence of tasks that each crewmember must perform to accomplish the mission. From this simulation, the program will generate total workload estimates for each of the five workload components (visual, auditory, cognitive, psychomotor, and kinesthetic) by summing the individual workload ratings for all the tasks that are performed concurrently. The total component workload predictions will be generated for every half-second interval in the segment. The estimates of component workload will identify points on the mission timeline where excessive workload (i.e., overload) will occur. Thus, predictions of total workload associated with the performance of concurrent and sequential tasks in the AH-64A baseline configuration will be generated.

In the fourth task, the results of the simulation will be reviewed to identify and correct any errors in the task/workload analysis data base. In addition, AH-64A subject matter experts will review the computer simulation of the crewmembers' actions during each mission segment to ensure that the model conforms with typical crewmember actions.

Validation of the AH-64A Workload Prediction Model

During the second project, the TAWL methodology and the AH-64A workload prediction model will be validated. The workload predictions yielded by the model will be evaluated by conducting part-mission and full-mission simulation research. In each instance, predictions of workload for specific tasks will be compared with objective measures of primary task performance, physiological measures of workload, and subjective measures of workload (e.g., Reid, Shingledecker, & Eggemeier, 1981; Hart & Staveland, 1987).

Finally, the results of the validation research will be used to refine the model. The research to validate the AH-64A model will not only establish the accuracy of the predictions of AH-64A workload prediction model, but will also establish the utility of the TAWL methodology for producing valid models of operator workload.

Workload Analysis of the Longbow Apache

During this project, the AH-64A computer model will be modified and exercised to predict how crew workload might be affected by the changes made to the Longbow model. The project consists of the following steps:

- establish a secure computer system for developing the model,
- identify the design changes that affect the operation of the system,
- conduct a task/workload analysis for each change,
- develop the function and segment decision rules for the changes,
- exercise the Longbow model to yield estimates of workload, and
- compare the estimates of workload for the baseline and Longbow configurations.

The results of this project will be used to estimate the differences in crewmember workload between the AH-64A and the Longbow Apache. The estimates, in turn, will assist design engineers in identifying the configuration of the AH-64 that produces lower operator workload.

Work Completed

Development of the AH-64 Workload Prediction Model

During the first year of the current contract, both the task/workload analysis and the decision rules were extensively reviewed and revised. In addition, a preliminary version of the computer model, using a Perkin-Elmer minicomputer and FORTRAN language, was developed. The model was exercised to produce preliminary analyses of workload for each of the mission segments.

During the second contract year, the AH-64A mission/task/workload analysis was reprogrammed using the TOSS software. The AH-64A workload model was exercised to produce mission segment printouts, which were reviewed to ensure that the computer model accurately simulated the function and segment decision rules. In some cases, the function and segment decision rules were revised.

During the current contract year, Anacapa researchers developed the capability to graph the output of TOSS models. A review of the graphic output identified a number of inaccuracies in the decision rules that require revision. By the end of the current contract year, the AH-64A baseline workload prediction model was being revised to increase its accuracy. The changes included substituting interval rating scales for ordinal workload scales, revising the task/workload analysis, and revising the function and segment decision rules.

Validation of the AH-64A Workload Prediction Model

During the current contract year, a draft validation research plan was written. The research plan stipulates the measurement of several objective and subjective measures of operator workload that will be used as validation criteria. In addition, a request was prepared and submitted to Forces Command (FORSCOM) for support in validating the AH-64A model.

Workload Analysis of the Longbow Apache

During the current contract year, a secure computer system was established for developing the Longbow Apache workload prediction model. The major modifications to the Longbow Apache were identified, changes to the composite mission scenario resulting from the modifications were analyzed, and the additional segments needed to model the changes were identified. At the close of the current contract year, work had begun on the task/workload analysis of the Longbow Apache.

Work Projected

Development of the AH-64 Workload Prediction Model

During the next contract year, the revised model will be exercised to produce estimates for each of the 52 unique mission segments. These predictions will be reviewed to produce the final baseline version of the AH-64A model. The technical report by Szabo and Bierbaum (1986) will be revised to reflect the final version of the AH-64A model. The workload predictions produced by the exercise of the model will be described in a research report.

Validation of the AH-64A Workload Prediction Model

The draft research plan for validating the AH-64A model will be completed and submitted to ARIARDA for approval. Upon completion of the AH-64A model revisions, ARIARDA approval of the research plan, and approval for using FORSCOM resources, the validation research will begin. A report describing the results of the research will be prepared when the validation effort is completed.

Workload Analysis of the Longbow Apache

The task/workload analysis will continue. The necessary function and segment decision rules will be developed and the model will be programmed using the TOSS software. The model will be exercised and the workload predictions will be compared to AH-64A model predictions. Finally, a research report will be prepared to document the results of the model's predictions and the comparisons between the two AH-64 models.

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UH/MH-60 AND CH/MH-47 TASK/WORKLOAD ANALYSES

Mr. Carl R. Bierbaum, Project Director

Background

The Special Operations Aircraft (SOA) Program Manager's (PM) office at the Army's Aviation Systems Command has been tasked to develop an MH-60K and an MH-47E aircraft to support the Special Operations Forces. The SOA will consist of existing CH-47D and UH-60A airframes with increased power and new integrated cockpits. The integrated cockpit will replace the existing instrument and gauge configuration in both the CH-47D and UH-60A aircraft with four multifunction display (MFD) units.

The effect that the high technology modifications being proposed for the MH-60K and the MH-47E may have on crewmember workload must be evaluated to ensure that the crewmembers can utilize the many MFD options effectively. Anacapa Sciences personnel, under contract to the Army Research Institute Aviation Research and Development Activity (ARIARDA), have developed a methodology for predicting operator workload during system design. The workload prediction methodology was developed during the design of the Army's light helicopter aircraft (LHX) (Aldrich, Craddock, & McCracken, 1984; Aldrich, Szabo, & Craddock, 1986). The LHX methodology was subsequently refined and used to develop baseline workload prediction models for the AH-64A Apache (Szabo & Bierbaum, 1986), the UH-60A Black Hawk (Bierbaum, Szabo, & Aldrich, 1989), and the CH-47D Chinook (Bierbaum & Aldrich, 1989). Because ARIARDA had developed a successful methodology for conducting mission/task analyses and predicting workload, the SOA Aviation Project Office requested that ARIARDA develop a SOA scenario, conduct the mission/task analyses, and predict the crewmember workload for the MH-60K and MH-47E aircraft.

Research Objectives

The overall objective of this research area is to determine the effect that the integrated cockpit modifications are likely to have on the workload of UH-60A and CH-47D crewmembers. Specifically, the research is designed to:

- provide a mission/task analysis of the UH-60A and the MH-60K,
- determine the effect that the proposed MH-60K modifications will have on crew workload,

- provide a mission/task analysis of the CH-47D and the MH-47E, and
- determine the effect that the proposed MH-47E modifications will have on crew workload.

Research Approach

The approach selected for meeting the research objectives is a refinement of the Task Analysis/Workload (TAWL) methodology that was developed for the LHX and the AH-64A research projects. The UH/MH-60 and CH/MH-47 workload analyses are divided into the following four projects:

- In the first project, a baseline mission/task analysis of crew workload will be conducted and a computer model of crewmember workload will be developed for the UH-60A helicopter.
- In the second project, a baseline mission/task analysis of crew workload will be conducted and a computer model of crewmember workload will be developed for the CH-47D helicopter.
- In the third project, a mission/task analysis of crew workload will be conducted and a computer model of crewmember workload will be developed for the MH-60K helicopter. The UH-60A and the MH-60K workload prediction models will be exercised and compared to predict the effect that the MH-60K design modifications are likely to have on crewmember workload.
- In the fourth project, a mission/task analysis of crew workload will be conducted and a computer model of crewmember workload will be developed for the MH-47E helicopter. The CH-47D and the MH-47E workload prediction models will be exercised and compared to predict the effect that the MH-47E design modifications are likely to have on crew workload.

Work Completed

UH-60A Task Analysis and Workload Prediction Model

The development of the UH-60A workload prediction model was completed during the first contract year and was reported in the 1987 Annual Summary Report (Bierbaum, 1988) and in a research report by Bierbaum, Szabo, and Aldrich (1989).

CH-47D Task Analysis and Workload Prediction Model

The development of the CH-47D workload prediction model was completed during the second contract year and was reported in the 1988 Annual Summary Report (Bierbaum, 1989). A report of the CH-47D workload prediction model was completed in January 1989 and submitted to ARIARDA (Bierbaum & Aldrich, 1989).

MH-60K Task Analysis and Workload Prediction Model

The development of a mission scenario and the mission phases was completed during the second contract year and was reported in the 1988 Annual Summary Report (Bierbaum, 1989). During the current contract year, work continued on the MH-60K task analysis and on the development of an MH-60K workload prediction model. The completed project tasks are briefly described below.

Develop a mission scenario. The MH-60K mission begins with a departure from a base site. The pilot flies contour from the base to a rendezvous point, where air-to-air refueling is accomplished. After refueling, the pilot flies nap-of-the-earth (NOE) from the rendezvous point to the landing zone (LZ). The pilot then flies back to a rendezvous point for refueling and continues to the base. The complete mission is conducted at night with night vision goggles. Preflight and postflight activities are not included in the analysis.

Divide the mission scenario. The mission scenario was divided into five phases for analysis. The five mission phases were further divided into 15 unique segments. Some segments are used in more than one of the phases. The number of segments in each phase is listed below:

- Departure (Base) - 3,
- Enroute (Base-Rendezvous) - 4,
- Enroute (Rendezvous-LZ) - 4,
- Enroute (LZ-Rendezvous) - 4, and
- Enroute (Rendezvous-Base) - 3.

Divide the segments into functions and tasks. The 15 unique segments were divided into 71 unique functions. Each function was described, alphabetized, and assigned a numerical identification code for entry into the MH-60K workload model. The 71 functions were then divided into 234 tasks. Each unique task was described, alphabetized by object, and assigned a numerical identification code for use in the workload model.

Identify the subsystems associated with each task. Seventeen aircraft subsystems were identified on the MH-60K. The subsystems were divided into five major categories: Engine, Flight Control, Navigation, Utility, and Visual. The subsystems were coded and entered into the workload model so that crewmember overloads could be associated with the specific subsystems in use when each overload occurred.

Estimate the workload and time required for each task. A short verbal description of each of the five workload components (visual, auditory, cognitive, psychomotor, and kinesthetic) was written for each task. The descriptors were then compared to the verbal anchors contained in 7-point rating scales designed for rating each of the workload components. The appropriate scale value for each component was entered into the MH-60K model as an estimate of the task workload.

The Integrated Avionics Subsystem (IAS) to be installed in the MH-60K cockpit was not available for an empirical analysis of the time needed to perform each task. Instead, the time assigned to each task was estimated by subject matter experts in the IAS Crewstation Working Group.

Develop and exercise the MH-60K model. The specific tasks identified during the analysis were entered into the TAWL Operator Simulation System (TOSS) data files. The researchers developed the decision rules required to combine specific tasks into functions and to combine the functions into segments. The decision rules were then programmed and the workload prediction model was exercised to provide estimates of component workload at each half-second interval for each segment in the scenario.

MH-47E Task Analysis and Workload Prediction Model

During the current contract year, work continued on the MH-47E task analysis and on the development of an MH-47E workload prediction model. The mission scenario, mission phases, segments, and functions for the MH-47E are the same as those identified for the MH-60K. However, only 230 tasks were identified for the MH-47E.

Develop and exercise the MH-47E model. The specific tasks identified during the analysis were entered into data files for the workload prediction model. The researchers developed decision rules to combine the tasks into functions and to combine the functions into segments. The decision rules were then programmed and the workload prediction model was exercised to provide estimates of component workload at each half-second interval for each segment in the scenario.

Work Projected

MH-60K and MH-47E Workload Prediction Models

During the next contract year, the MH-60K workload predictions will be compared with the UH-60A workload and the MH-47E workload predictions will be compared with the CH-47D workload. Finally, two research reports will be prepared to document the results of the analyses.

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VALIDATION OF THE LHX WORKLOAD PREDICTION MODEL

Mr. Theodore B. Aldrich, Project Director

Background

Models that predict operator workload can be useful tools for human factors engineers who are addressing human capabilities and limitations during the design of advanced technology weapon systems. Accordingly, Anacapa Sciences researchers, under contract to the U.S. Army Research Institute Aviation Research and Development Activity, developed a workload prediction methodology and produced one- and two-crewmember models for predicting aviator workload in advance of aircraft system design. The workload prediction methodology operationally defines workload in terms of attentional demand and predicts workload associated with task-level performance. The Anacapa researchers applied the workload prediction models during the conceptual design phase of a proposed multipurpose, lightweight helicopter designated the LHX (Aldrich, Szabo, & Craddock, 1986).

Need

Neither the workload predictors used to develop the models nor the workload predictions yielded by the models have been validated. Workload model predictors that require validation include the:

- workload ratings assigned to each task,
- total workload estimates for concurrent tasks,
- estimated time required to perform each task,
- temporal relationships among tasks, and
- sequential relationships among tasks.

Specific predictions yielded by the models that require validation include the four indexes of excessive workload (Aldrich, Craddock, & McCracken, 1984) listed below:

- component overloads,
- overload conditions,
- overload density, and
- subsystem overloads.

Research Objectives

This project is divided into three phases. The objectives of Phase 1 are to evaluate the reliability of (a) the scales used to rate the workload components of each operator task identified during the LHX workload analyses and (b) the workload predictors used in developing the LHX workload prediction model. The objective of Phase 2 is to obtain validation data through part-mission and full-mission flight simulation research. The objective of Phase 3 is to refine the workload prediction model on the basis of the validation research results.

Research Approach

The research plan (Aldrich & Szabo, 1986) describes 18 tasks that are required to accomplish the three phases of the validation research. A summary of the research methodology for each of the three phases is described below.

Phase 1

In Phase 1, two surveys will be administered to approximately 70 human factors scientists who are familiar with workload research. In the first survey, all possible pairs of the verbal anchors from each of the workload component rating scales will be presented to the workload subject matter experts (SMEs). The SMEs will select the anchor in each pair that requires the greatest attentional demand. The results of this survey will be used (a) to assess the interrater reliability of the scale anchors and (b) to derive equal interval scales (e.g., Engen, 1971) to replace the ordinal scales used in the original workload analysis.

The second survey will ask the same SMEs to use the workload component scales to rate the short descriptors of visual, auditory, cognitive, and psychomotor components of workload for each task in the model. Correlational techniques will be used to evaluate the interrater reliability of the workload ratings.

Phase 2

In Phase 2, part-mission and full-mission simulation experiments will be conducted to validate the workload estimates. For the part-mission simulation, mini-scenarios will be generated by selecting concurrent and sequential tasks from the mission/task analysis. For the full-mission simulation, a composite mission scenario will be developed by selecting segments from the mission/task analysis.

The part-mission simulation experiments will be conducted using a repeated measures experimental design in which each subject will fly the mini-scenarios multiple times. The results will be analyzed by correlating the workload predictors and the measures of the operators' performance on the concurrent and sequential tasks. The correlation coefficients will indicate how accurately the workload predictors forecast excessive workload at the task level. To validate the time estimates used in the model, the time required to perform the various tasks in the mini-scenarios will be compared with the time estimated during the task analysis. The procedural relationships among the tasks will be evaluated by assessing the subjects' ability to progress through the mini-scenarios following the sequence of tasks specified by the model.

During the full-mission simulation experiments, each trial will start at the beginning of a composite scenario and continue without interruption to the end. All the part-mission simulation data analyses will be conducted on the full-mission simulation data. In addition, an analysis will be performed to assess the effects of inserting secondary tasks into the composite mission scenario.

The final task in Phase 2 will be to compare the results from the part-mission simulation research with results from the full-mission simulation research. The findings from this comparison will be used to determine if excessive workload results from the cumulative effects of high workload over the longer times in the composite mission scenario.

Phase 3

In Phase 3, refinements will be made to the workload prediction model on the basis of the results from the first two phases. First, the workload component rating scales will be converted from ordinal to interval scales. Second, refinements will be made to the workload model algorithms to reflect the empirical results of the part-mission and full-mission simulation experiments.

Work Completed

Phase 1

The first survey was conducted during the second contract year. A survey form was developed that presented all possible pairs of the verbal anchors from each of the four workload component rating scales. The survey forms were mailed to 71 SMEs who were asked to select the verbal anchor in each pair that was judged to require the greatest attentional demand. Completed data forms were received from 38 SMEs. Kendall's Coefficient of Concordance (Siegal, 1956) was used to assess the degree of agreement among the SMEs. The coefficients for the four scales ranged from .39 (visual) to .69 (cognitive). All of the coefficients are significant at the .001 level and indicate moderate agreement among the SMEs about the attentional demand for each verbal anchor.

Phase 2

In October 1987, the new Crew Station Research and Development Facility (CSRDF) located at the the Army's Aeroflightdynamics Laboratory, NASA Ames, Moffett Field, California, was selected as the most appropriate site for conducting the validation research. The LHX part-mission simulation research was scheduled for October 1988, January 1989, and April 1989. The LHX full-mission simulation research was scheduled for July through September of 1989.

In April 1988, CSRDF planners postponed the simulation research for October 1988 until October 1989 because of delays in acquiring a new Compuscene IV visual system and because of changes in research priorities. CSRDF simulation planners also stated that the initial LHX validation research should be full-mission simulation with two crewmembers. This differs from the project research plan that begins with the part-mission, one-crewmember simulation.

Phase 3

During the second contract year, the data from the pair comparison survey were used to derive interval values for the workload component scales. The workload prediction model was refined by replacing the original ordinal values for each task with the interval values. The one-crewmember workload model was exercised with the new interval scale values to produce estimates of workload for each of the 29 mission segments in the model. A comparison of the workload predicted by the two sets of scales showed that, although there are some differences, the interval scale estimates closely correspond to the ordinal scale estimates.

Work Projected

Because of the repeated delays in access to the CSRDF simulation facilities and CSRDF changes to the simulation design, this project was discontinued in April 1989. No further work is projected. The need to validate the Anacapa Sciences/ARIARDA workload prediction methodology will be met by evaluating the AH-64 model predictions.

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DESIGN AND APPLICATION OF FLIGHT SYMBOLOGY

Dr. Richard Weeter, Project Director

Background

The AH-64A attack helicopter is the first Army aircraft to feature the Pilot Night Vision System (PNVS). The PNVS is a display system that enables crew members to conduct attack missions at night and in adverse weather by providing an infrared image of the external visual scene. The PNVS presents a 30° x 40° field of view to the pilot's right eye via a 1 inch in diameter cathode ray tube mounted on the pilot's helmet. A set of 27 symbols, intended to provide critical flight and targeting information, can be projected onto the field of view.

The PNVS symbology consists of alphanumeric, position, size, and shape-coded symbols. Some of the symbols, such as the heading scale and lubber line, are adaptations of traditional electro-mechanical instruments that appear at fixed locations on the display. Many of the other symbols are unique, dynamic representations of spatial information. Symbols, such as the projected center line of the aircraft or the computed impact points of weapons, may appear, disappear, or move on and off the display as a result of changes in the aircraft or sensor orientation.

Prior to the development of the PNVS in the late 1970s, Schmit (1977) found little empirical research to suggest a basis for the evaluation of potential symbology formats. During the development of the PNVS symbology format, Buckler (1978a) described the state of empirical research comparing different formats as sorely lacking. Furthermore, Buckler (1978b) reported that reconfigurable simulators were not readily available to test alternative symbology formats for the PNVS.

To date, no empirical research has been identified that evaluates whether the PNVS symbology format enhances or degrades information transfer during mission tasks. Nevertheless, the current Department of Defense military standard for symbology formats, MIL-STD-1295A(AV), is patterned after the AH-64A PNVS symbology set (Department of Defense, 1984). In the foreword of that document, the authors acknowledge the need for research on symbology format design. Historically, however, the development of symbology has been evolutionary rather than systematic (Shrager, 1977). An example is the symbology developed for the Army's MH-60K and MH-47E special operations helicopters (International Business Machines, 1988). Different symbols are used to present some of the same basic flight information represented in the PNVS symbology format, but no information is publicly available to explain how the new symbols were developed or how the new symbology format will affect crew performance.

Need

Currently, there is no widely accepted research methodology for addressing critical symbology design issues or for evaluating the effectiveness of existing symbology sets. As a result, there are no empirically valid design criteria for new aircraft display symbology. Therefore, a methodology is needed to evaluate the effectiveness of the AH-64A PNVS symbology set, which represents the current military standard in symbology formats.

The research methodology must address whether the symbol coding dimensions are compatible with the cognitive processes of AH-64A crewmembers. Ideally, successive experiments will culminate in the development of symbol and display format design criteria. The resultant symbology should (a) be compatible with the known visual and cognitive capabilities of aviators, (b) present information that can be interpreted accurately and efficiently under stressful conditions, and (c) complement rather than interfere with information available from the natural external visual scene and from sensor-provided imagery.

The Army Aviation Systems Command (AVSCOM) tasked the Army Research Institute Aviation Research and Development Activity (ARIARDA) to initiate research to meet these needs. Anacapa Sciences personnel began work on the project in February, 1987.

Project Objectives

There are three objectives of this project are (a) to develop a methodology for evaluating aircraft display symbology, (b) to conduct empirical evaluations of the existing AH-64A PNVS symbology, and (c) to identify potential design criteria for modifying the current AH-64A PNVS symbology and for developing future aircraft display symbology.

Research Approach

Following a review of the literature, a selective visual attention approach was chosen to evaluate the PNVS symbology because it provides a method of empirically comparing the demand of attending to visual stimuli. In some types of selective visual attention paradigms, subjects perform fundamental visual tasks similar to those required of pilots using aircraft visual displays (e.g., Lyon, 1987; Williams, 1982). Such experiments have revealed that a number of factors affect attentional performance on visual tasks. For example, Eriksen and Hoffman (1972) demonstrated that efficient encoding of information from visual displays can be detrimentally affected by the number, nature, and proximity of noise elements. Pilots using aircraft visual displays with several symbols in close proximity, a condition described as display clutter, have reported similar encoding difficulties. Lyon suggested that rapid attention shifts may be a measurable component of skilled performance in vision dependent tasks.

The cueing procedure for the cued line-of-sight (LOS) symbol in the AH-64A PNVS symbology set was selected for the initial evaluation. The purpose of the cued LOS symbol is to indicate to the pilot where the copilot-gunner is looking. The procedure uses two different cues, a one-dot cue and a two-dot cue, to indicate one of the eight search areas in the PNVS field of view. The cueing dots also have a secondary purpose: they flash to indicate that an Integrated Helmet and Display Sighting System (IHADSS) boresight is required.

Three experiments were designed to evaluate the cued LOS symbol; the experiments address differences in the one- and two-dot conditions, differences in presentation duration, the effects of the secondary cueing meaning, and the effects of practice on cueing accuracy. In addition to evaluating the cued LOS symbol, the experiments were designed as a test of the selective attention paradigm for evaluating symbology design. If the results of the initial test are positive, then additional symbols will be selected for evaluation.

Work Completed

Between November 1988 and March 1989, three selective visual attention experiments were conducted to evaluate the PNVS cueing procedure. Experiment 1 was conducted to evaluate the task demand of attending to each of three cueing conditions: no-dot, one-dot, and two-dot. The results from six subjects indicate that attending to the two-dot cue is more difficult than attending to the one-dot cue at the fastest presentation durations. Accuracy was significantly higher in the no-dot condition except at the slowest presentation duration. In the one- and two-dot conditions, accuracy increased as the presentation duration increased; at 133 ms, the average percentage of correct identifications was approximately 94%.

Experiment 2 evaluated the effectiveness of the one- and two-dot cues in a target acquisition task. For the 10 subjects in Experiment 2, the one-dot cue was more effective than the two-dot cue at presentation durations of less than 267 ms. As in Experiment 1, accuracy increased as the presentation duration increased. Performance gradually improved for both the one- and the two-dot cues during the first 768 trials. There was no significant improvement for either cue between 768 and 1,280 trials.

In Experiment 3, the same 10 subjects who participated in Experiment 2 continued to perform the target acquisition task, but on one-half of the trials the cueing dots flashed to simulate an IHADSS boresight requirement. Accuracy with both the one- and two-dot cues was significantly degraded by the presence of flashing dots. The subjects showed no significant improvement in accuracy across trials.

The results of the three experiments indicate that (a) the two cueing methods (one- and two-dot) are differentially effective in cueing shifts of visual attention at short presentation durations, (b) the ability to use the cues improves with practice, and (c) the secondary purpose of the cueing dots significantly interferes with their primary purpose. Furthermore, the ability of the selective visual attention paradigm to detect these effects indicates that it is an appropriate method for evaluating some aspects of existing and proposed aircraft display symbology formats.

At the end of the contract year, a report describing the literature in selective visual attention and the three experiments evaluating the cued LOS was drafted and submitted for internal review.

Work Projected

The draft report for this project will be revised and submitted to ARIARDA early in the following contract year. If directed by ARIARDA, further research will be conducted to evaluate other symbols in the PNVS symbology set.

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HUMAN FACTORS DESIGN FOR MAINTENANCE OF ARMY AVIATION SYSTEMS

Dr. John W. Ruffner, Project Director

Background

Increasingly complex aviation systems are being developed to enhance the ability of Army aviators to fight and survive on the modern battlefield. However, these systems are often designed with little regard for the mental and physical capabilities and limitations of the soldiers who are required to operate and maintain them.

Some progress has been made in designing aviation systems to be consistent with the capabilities and limitations of the operator; however, comparatively little attention has been paid to designing systems to improve their maintainability. Traditionally, the maintainability of a system is given the lowest priority during the design process, with maintainability being secondary to performance, cost, and operability criteria. By the time maintainability problems are identified, changes for the sake of efficient maintenance are often not feasible. Furthermore, efforts to increase system performance and operability often result in added system complexity, with a concomitant increase in maintenance requirements (Bond, 1987).

Maintenance costs are often the most important element in the life-cycle cost estimates for an aviation system. A typical breakdown is approximately 15% for design, 35% for production, and 50% for operation and support. The proportion of the Department of Defense annual budget required for maintenance has been estimated to be between 25% and 30%. Furthermore, the total maintenance costs of a piece of equipment throughout its life cycle are often expected to exceed its acquisition costs.

This situation is exacerbated by the projected shortfall in the number of military-age individuals who will be available for maintaining complex aviation systems. The personnel who will be recruited into the military services in the next 20 years will be fewer in number and of lesser aptitudes and capabilities than at present. The military services will have to compete with the civilian job market for the most capable individuals. In addition, only a small percentage of military aviation technicians serve more than a 4-year enlistment period. This makes it extremely difficult for the majority of maintenance technicians to achieve the skill level required to maintain complex aviation systems.

Smith, Westland and Crawford (1970) identified three potential solutions to the problem of adequately maintaining complex military systems: (a) improve technician skills through training, (b) improve job performance (e.g., trouble-shooting aids), and (c) improve equipment design. They argued, however, that efforts to provide better training were not succeeding in reducing the maintenance problem. In addition, there had been negligible increases in the effectiveness of job performance aids.

Smith et al. (1970), among others, emphasize the need to improve maintainability by influencing the design of systems as early as possible during the acquisition process. They argue that equipment design is the most important factor contributing to the level of maintainability and that there is a pressing need for data, methods, and models that specify human factors inputs to the engineer during system development.

More recently, the Department of Defense MIL-STD-470A (1983) stated that manpower and personnel shortages are of such magnitude that the maintainability problem must be approached through the design process as well as through the more traditional approaches of improving training and providing job performance aids. One of the primary objectives of the Army's Manpower and Personnel Integration (MANPRINT) program is to influence the design of military systems so that they can be operated and maintained in the safest and most cost-effective manner consistent with the manpower structure, personnel aptitudes and skills, and training resource constraints of the Army (Department of the Army, 1987).

Need

In response to the Army's MANPRINT initiative, several procedural methodologies and models for applying knowledge about the capabilities and limitations of human operators and maintainers to the design of military systems have been developed or modified. The majority of this work has been directed toward the role of the human as system operator rather than as system maintainer. Methodologies and models are also needed that can be applied toward improving the maintainability of aviation systems as early as possible in the system design and acquisition processes. In December 1987, the Army Research Institute Aviation Research and Development Activity (ARIARDA) requested that Anacapa Sciences initiate a program of research to address human performance problems in the area of Army aviation maintenance.

Research Objectives

The objective of this research area is to identify or develop human factors methodologies and models that might be used to improve the maintainability design of emerging Army aviation systems.

Research Approach

The first project in this research area is to review the literature on Army aviation maintenance, maintainability design, and human factors methodologies and models that might be used to improve maintainability design. The second project is to conduct a maintenance task analysis of selected Army aviation systems. The task analysis is a precursor to the development of a model of maintainer performance and workload.

Work Completed

Survey of Methodologies and Models

Beginning in December 1987, approximately 130 documents related to maintenance design were identified and reviewed. The documents include maintainability engineering textbooks, maintainability guidelines, military standards and handbooks, Army regulations, field manuals, technical manuals, literature reviews, technical reports, journal articles, and professional papers. Ninety-nine of the documents reviewed were retained for citation in the project report.

Three comparability methodologies and seven behavioral simulation models (both operator models and maintainer models) were identified that have potential for improving the maintainability design of emerging Army aviation systems. The literature on each methodology and model was reviewed to determine its relative utility for improving maintainability design.

Summary of results. All of the methodologies and models reviewed were judged to have some utility for improving the maintainability design of emerging Army aviation systems. However, the utility of the three comparability methodologies is limited because they (a) produce little direct insight about the design changes required to improve maintainability, (b) tend to perpetuate poor maintainability design features and personnel practices, (c) rely extensively on expert judgment, and (d) are very time consuming and labor intensive. Because of these problems, the comparability methodologies are not recommended for improving maintainability design.

The utility of the four operator models is limited because they do not account for many of the characteristics that distinguish system maintenance from system operation. In addition, each of the models has specific deficiencies that limit its utility for simulating maintainer performance. Therefore, the operator models, in their present forms, are not recommended to simulate maintenance performance and to predict maintainer workload.

The Maintenance Personnel Performance Simulation (MAPPS) model was developed to simulate maintainer performance in the nuclear power plant environment. The extent to which the MAPPS model may be useful for improving the maintainability design of emerging aviation systems depends on the similarity between maintenance tasks and working conditions in a nuclear power plant and those in an Army aviation maintenance environment.

The Crew Chief and Profile models were developed to simulate maintainer performance in the two types of activities that require the majority of maintainers' time: (a) accessing, removing, and replacing equipment and (b) fault detection and troubleshooting. Of the methodologies and models reviewed, Crew Chief and Profile were judged to have the greatest potential for improving the maintainability design of emerging Army aviation systems.

Recommendations. A draft report summarizing the results of the literature review was completed and submitted to ARIARDA for formal review in February, 1989. ARIARDA personnel completed their review in May, 1989. The draft report was revised and resubmitted in final form (Ruffner, 1989) to ARIARDA in August, 1989. In the report, it was recommended that the Army:

- evaluate the Crew Chief and Profile models to determine their utility for improving the maintainability design of Army aviation systems, and
- evaluate the four operator models and the MAPPS model to determine the feasibility and desirability of modifying them to simulate the performance of maintainer tasks not addressed adequately by the Crew Chief or Profile models.

Furthermore, ten criteria, drawn from the maintenance and maintainability design literature, were proposed to guide the development and evaluation of maintenance design methodologies and models.

In addition, it was recommended that three additional research tasks be undertaken to address maintainer performance issues in Army aviation systems and operational environments:

- conduct maintenance task and workload analyses for selected Army aviation systems and equipment as a precursor to the development of a model of Army aviation maintainer performance and workload;
- monitor research and development efforts to develop expert system/CAD maintainability design models that could apply to Army aviation systems; and
- conduct a comprehensive review of the literature on troubleshooting performance, especially as it applies to Army aviation systems, and monitor ongoing research and development activities in this area.

Maintenance Task Analysis

After reviewing the first project report, ARIARDA requested that Anacapa Sciences initiate a task analysis of selected Army aviation tasks. Work on this project began in March 1989 with a review of the literature relevant to maintenance task analysis. In addition, the U.S. Army Aviation Systems Command in St. Louis, Missouri, was contacted to identify sources of reliability and maintainability information for fielded and emerging Army aviation systems. At the end of the current contract year, the literature review was completed and work had begun on the development of a research plan.

Work Projected

Survey of Methodologies and Models

Submission of the final report completed Anacapa Sciences' work on this project.

Maintenance Task Analysis

The research plan will be completed and submitted to ARIARDA for formal review during the first quarter of the next contract year. After ARIARDA has reviewed and approved the plan, data collection activities will begin on this project. Following the data collection, the data will be processed and analyzed and a report will be prepared to document the project results.

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EVALUATION OF THE AVIATION RESOURCE MANAGEMENT SURVEY (ARMS) CHECKLIST

Dr. John W. Ruffner, Project Director

Background

According to the Army's "total force" concept, Reserve Component (RC) aviators serving in the U.S. Army Reserve (USAR) and the Army National Guard (ARNG) are required to train to the same standards and to maintain the same level of flight proficiency and flight safety as aviators serving in the Active Component. However, RC aviators must meet these requirements with less resources (e.g., aircraft, training time, flying hours, instructor pilots) than Active Component aviators. Therefore, the individuals who are responsible for planning, implementing, and evaluating RC training must manage the available resources efficiently.

One of the ways that the Army helps RC training managers achieve efficiency is through evaluation visits from Aviation Resource Management Survey (ARMS) teams. As defined by U.S. Army Forces Command (FORSCOM) Regulation 350-3 (1984), the ARMS has four specific objectives:

- to help commanders identify strengths and weaknesses in all aviation-related programs;
- to assess an aviation support facility's capacity to support the training of units assigned to the facility;
- to assess the aviation unit's capabilities (a) to operate safely, efficiently, and effectively and (b) to maintain aviation resources apart from the support facility while accomplishing its mobilization mission; and
- to identify problems and coordinate assistance required to solve problems that are beyond the facility commander's or unit commander's sphere of authority.

The Deputy Chief of Staff for Training (DCST) in each of the five Continental U.S. Armies (CONUSAs) is responsible for conducting ARMS evaluations. According to FORSCOM Regulation 350-3, an ARMS is to be conducted at least once a year for each USAR facility and unit and at least once every two years for each ARNG facility and unit within the CONUSA.

Problem

Each CONUSA has its own procedure for carrying out the ARMS evaluation program. There is a lack of standardization across the CONUSAs in (a) the functional areas (e.g., safety, standardization, and training) that are evaluated, (b) the procedures used by the ARMS teams to assess the facilities and units, and (c) the standards for acceptable performance.

The First U.S. Army DCST, Aviation Division, has developed a checklist to be used by the ARMS team during its evaluation visits. The checklist originally was published in October 1983, and republished in August 1985, as First Army Pamphlet 95-1. The checklist draws from two sources: FORSCOM Form 14-1-R, "Reserve Component Aviation Resource Management Checklist" (1980), and the U.S. Army Safety Center, "Guide to Aviation Resources Management for Aircraft Mishap Prevention" (1984).

The First Army checklist contains 670 items divided into the following 11 major functional areas of evaluation:

- Aviation Safety Management,
- Facility/Unit Operations,
- Aviation Standardization and Training,
- Aircraft/Flightline Operations,
- Aeromedical Management,
- Aircraft Crash Rescue and Fire Fighting,
- Petroleum, Oil, and Lubricants,
- Maintenance Management,
- Aviation Armament,
- Aviation Life Support Equipment, and
- Physical Security.

Each checklist item describes a specific deficiency that may result in (a) the failure of a facility to accomplish its mission of supporting its assigned RC units or (b) the failure of a unit to accomplish its mobilization combat mission. The checklist items were written by aviation subject matter experts who are knowledgeable about the operational requirements of RC support facilities in each of the functional areas or the mobilization mission requirements for RC units.

The DCST, First U.S. Army, has expressed concern about the content of the checklist, the manner in which the checklist items are used to evaluate RC facilities and units, and the management and utilization of information obtained from ARMS visits. Consequently, during the second quarter of fiscal year 1985, the DCST requested that the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) provide research support to evaluate and revise the checklist. Anacapa Sciences began work on the project on 3 June 1985.

Research Objectives

There are three general objectives of the ARMS Checklist research:

- systematically evaluate the content of the First U.S. Army ARMS Checklist,
- develop recommendations for improving the ARMS checklist and the procedures used to administer it, and
- develop a computer-based information management system for organizing and analyzing ARMS checklist data.

Research Approach

A preliminary review of the ARMS Checklist identified seven general deficiencies in the checklist and administrative procedures:

- The ARMS Checklist is excessively long and there are many items that may not be highly related to mission success.
- The procedures used to evaluate checklist items and to combine ratings from the various functional areas into an overall rating are not standardized.
- The negatively stated item format does not allow an inexperienced evaluator to focus on the specific subject in the item to be evaluated.
- The items are not listed in an order that allows an inexperienced evaluator to proceed through the evaluation steps efficiently.
- The items are not identified as applying specifically to an aviation facility, an aviation unit, or both.
- Many items are too general to be associated with observable conditions or events.
- There is no systematic procedure for collating information about commonly occurring deficiencies observed across facilities or units.

The preliminary review led to the development of three criteria for determining if an item should be retained in the checklist. Specifically, an item should be retained in the checklist only if the attribute addressed in the item is (a) easily detectable during an ARMS visit (Detectability), (b) important for judging the status of one of the functional areas (Importance), and (c) critical for mission success (Criticality). A survey questionnaire was developed to assess the extent to which the checklist items meet the three criteria for a support facility and for a unit. A separate version of the questionnaire was developed for each of the functional areas. The respondents for the questionnaire were aviators and aviation technicians from First Army National Guard and Army Reserve aviation support facilities and aviation units.

Work Completed

Pretesting of the questionnaires was completed in November 1985. Following pretest and revision, the questionnaires were mailed to ARNG and USAR facilities in the First Army area. An average of 23 respondents completed a questionnaire in each functional area. Responses to the questionnaires were entered into a data base, verified, and analyzed. Preliminary results of the data analyses were briefed to the First Army DCST in June 1986, and to staff members of the Aviation Division, DCST, First U.S. Army in March 1987.

The results indicate that the deficiencies described in the majority of the checklist items are detected easily during an ARMS evaluation visit and are moderately important for assessing the functional areas in which they are presently classified. The results also indicate that a facility or unit with the deficiencies described in the majority of the checklist items could support most aspects of its mission, assuming that the deficiencies exist in isolation. The results suggest that a single version of the checklist needs to be developed, with each item presented as an affirmative question instead of a negative statement and clearly annotated to indicate whether it applies to a facility or to a unit.

A set of decision rules was developed to aid the military user in determining if items should be retained in their present form, revised, or deleted from the checklist on the basis of the item's Detectability, Importance, and Criticality ratings. The decision rules should be applied to both the facility and unit checklist item ratings.

An information data base was developed to summarize the checklist items' Detectability, Importance, and Criticality ratings and to record the evaluations of RC units and facilities during future ARMS evaluation visits. The data base was designed to enable the First Army ARMS team (a) to select items for retention, revision, or deletion using the decision rules, (b) to reorganize the checklist by grouping together items with similar content and reference publications, (c) to place the items in a sequence that minimizes evaluator effort, and (d) to utilize the data obtained from future ARMS visits more effectively (e.g., to identify commonly occurring deficiencies).

At the end of the second contract year, the draft technical report (Ruffner & McAnulty, 1987) was formally reviewed by ARIARDA and returned to Anacapa for revision. At the beginning of the current contract year, the report was revised and submitted to ARIARDA in final form. Volume I of the report, describing the background, method and results, was published in May 1989 as Technical Report 835 (Ruffner & McAnulty, 1989a). In addition, an article (Ruffner & McAnulty, 1989b) describing the methodology and results of this project was accepted for presentation at the 33rd Annual Meeting of the Human Factors Society.

Work Projected

Completion and submission of the draft final report completed Anacapa's work on this project.

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DEVELOPMENT AND VALIDATION OF THE NEW FLIGHT APTITUDE SELECTION TEST (NFAST)

Dr. D. Michael McAnulty, Project Director

Background

The Army's original selection battery, the Flight Aptitude Selection Test (FAST), was developed in response to the unacceptably high attrition rates in the Army flight training program during the 1950s. The FAST comprised two overlapping batteries, one for commissioned officer (CO) applicants and one for enlisted and civilian applicants to the Warrant Officer Candidate (WOC) program. Each battery yielded a fixed wing and a rotary wing aptitude score for each applicant (Kaplan, 1965). The FAST, implemented in 1966, resulted in a substantial reduction in the flight training attrition rates.

In 1975, the FAST was revised to produce a single, effective battery with fewer, shorter, and more reliably scored subtests. Eastman and McMullen (1978) selected 7 of the 12 FAST subtests for retention in the revised FAST (RFAST). Subsequently, they analyzed the item difficulties and item discrimination coefficients to select the items to be retained in each subtest. The RFAST, implemented in 1980, was approximately one-half the length of the original FAST.

Subsequent research, however, indicated the need to develop a new FAST (NFAST) battery. Lockwood and Shipley (1984) found that six of the seven subtests had adequate internal consistency and that the correlation between the RFAST score and performance in initial entry rotary wing (IERW) training was statistically significant. They concluded, however, that the low percentage of variance accounted for by the RFAST indicates that it has limited utility in predicting IERW performance. In addition, Smith and McAnulty (1985) found that the RFAST had marginal retest reliability and that there was a large increase in the average score on retesting, indicating a need for an equivalent form for use when retesting is required.

Finally, Oosterhof and Dohme (1984) identified several problems with the RFAST, including biased items, poor graphics quality, and the lack of an alternate form for retesting. Oosterhof and Dohme developed an alternate FAST to remedy the problems they had identified, but they did not develop any new tests for the selection battery.

Early in the development of the NFAST battery, research was conducted to identify the ability requirements for the successful completion of IERW training. Experienced IERW instructor pilots (IPs) were asked (a) to identify the tasks that are most indicative of successful performance in the primary and instrument phases of IERW and (b) to judge the type and importance of the abilities that are required to perform each task. The task-ability ratings for each IP were then transformed to a normally distributed, equal-interval scale using the method of successive intervals (McAnulty & Jones, 1984). Analyses of the transformed ratings indicated that 24 abilities in the psychomotor, perceptual, language, and cognitive domains were required for successful performance in IERW. These analyses were used to design a test specifications matrix to guide the development of the NFAST (McAnulty, Jones, Cohen, & Lockwood, 1984).

Nine new tests were developed for an experimental NFAST battery. Eight tests were each designed to measure a unique ability and one test was designed to measure a complex of abilities required for the successful completion of IERW training. The battery also included four standardized tests as marker variables. The 7-hour experimental battery was administered to 290 general population subjects at three military installations in the southeastern United States.

The results indicate that the complex ability test and six of the unique ability tests assess reliable individual differences in the abilities of interest (McAnulty, Cross, & Jones, 1986). The average difficulty levels of the seven tests are near the optimum level of .50; the test variances indicate the measurement of substantial individual differences; and the estimates of reliability are acceptable when test length and the design specifications are considered. The remaining two unique ability tests had undesirable psychometric characteristics or did not contribute any unique variance to the factor structure of the battery.

Need

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has a continuing requirement to evaluate and improve the tests that are used to select applicants for the Army IERW training program. As indicated in the Background section, an NFAST battery is needed to improve the reliability and validity of the IERW selection process and to provide an equivalent form to be used for retesting IERW applicants.

Research Objective

The general objective of this research area is to develop, evaluate, and implement a more effective battery of IERW selection tests. To accomplish this objective, the following research and development tasks must be performed:

- develop two alternate forms of the NFAST battery,
- conduct preoperational research to validate and equate the alternate forms of the NFAST battery,
- produce and pretest the operational versions of the NFAST battery, and
- implement and evaluate the NFAST battery and administrative procedures in operational use.

Research Approach

This research is part of the ongoing ARIARDA program in aviator selection and classification (McAnulty, 1986). The aviator selection research is divided into three projects. The initial project (NFAST Validation) is a predictive validity investigation. The results of the experimental battery analyses will be used to develop two alternate forms of an NFAST validation battery. The preoperational validation research will be conducted (a) to determine the relationship between the NFAST tests, other predictor data, and performance in IERW training and (b) to equate the alternate forms of the battery on a large sample drawn from the target population of flight students. During this project, measures of IERW performance will be identified and evaluated as flight training criteria.

The second project (Operational NFAST Development) is the development of the operational NFAST battery. The results of the validation analyses will be used to produce two alternate forms of the NFAST. In addition, all ancillary materials (machine scorable answer sheets, administrative manuals, scoring and equating manuals, selection criteria) will be prepared for operational use. The operational battery and ancillary materials will be pretested on a sample of current IERW students.

The third project (NFAST Implementation) is the implementation of the NFAST to select applicants for IERW training. When the NFAST is implemented, a sample of field data will be analyzed to ensure that the psychometric characteristics of the operational battery are not significantly different from the validation battery. In addition, data will be collected and analyzed to ensure that the tests are being administered properly and that the test scores are being used appropriately in the selection process.

Work Completed

Preoperational NFAST Validation

The validation battery development, data collection, and analysis activities on the NFAST Validation project have been completed. The results of the experimental battery research were used to develop two alternate forms of the NFAST validation battery. Each form consists of modified versions of the complex test and the six unique ability tests that had acceptable psychometric characteristics. In general, the validation battery tests are approximately two-thirds the length of the experimental battery tests. The alternate forms of five of the tests have 40% to 50% of the items in common. The complex ability test forms and one of the unique ability test forms do not have any identical items. Finally, a knowledge test of helicopter operations and aerodynamic principles was adapted from the RFAST battery for inclusion in the validation battery. The items on the knowledge test are identical on both forms. Each form of the validation battery requires approximately 4 hours to administer.

Between March and October 1987, the alternate forms of the NFAST battery were administered to approximately 97% of the CO and WOC flight students during their first week of IERW training. When the test administration segment was terminated, complete and usable test data were collected from 377 CO and 341 WOC students.

Test results. Analyses of the test data indicate that the flight student performance on the validation battery, excluding the helicopter knowledge test, is similar to the general population performance on the experimental battery. The average difficulty levels are near .50 despite the more restrictive time limits that were imposed on the validation tests, and the variances indicate that substantial individual differences in ability are being measured by the tests. The internal consistency estimates of reliability are also within an acceptable range. Performance on the two forms of the battery is very similar except for one of the unique ability tests. Test performance by the CO and WOC students is also quite similar, although the CO students scored significantly higher ($p < .01$) on four of the tests.

The results on the helicopter knowledge test indicate that the test is not difficult and that there is limited variability in the scores. WOC students scored significantly higher on the test than the CO students. However, there is no difference in performance by either student group on the two forms of the test. Because the two forms are identical, this result indicates there was no systematic sampling bias in terms of aviation-related knowledge in assigning students to the alternate forms of the NFAST battery.

Training results. Three types of IERW performance measures were collected on the students who participated in the NFAST validation: administrative changes (elimination and training setback data), flight hour data (number of flight hours required to complete each phase of training), and IERW training grades (academic and flight). The primary performance criterion was the Overall Average Grade (OAG), which is a weighted composite of the academic and flight grades. IERW performance data collection was completed in January 1989. Of the 718 students in the data base, 696 either completed IERW or were eliminated from training for flight or academic deficiencies; the remaining students were eliminated for nondeficiency reasons or were transferred for training under a different syllabus. The validation analyses were conducted using the 696 students who graduated or were eliminated for deficiency reasons.

Validation results. The results of the validation data analyses indicate (a) that the NFAST battery has good psychometric characteristics, (b) that the alternate forms are approximately equal, and (c) that a subset of the tests in the battery will significantly improve the IERW selection process. Across all subgroups (e.g. forms, ranks, training track, education levels), three of the tests (the complex test, one unique ability test, and the helicopter knowledge test) consistently had high regression coefficients (R of approximately .50) on the OAG and other criteria. Cross validation analyses indicated that the regression equations were stable when applied to the holdout samples. Finally, utility analyses demonstrated the improvements in training efficiency that could be obtained by using shortened versions of the three tests as the IERW selection battery.

In December 1988, the results of the preoperational validation research were presented at the annual conference of the Military Testing Association (McAnulty, 1988). At the end of the current contract year, a draft report was being prepared to document the results of the NFAST Validation project.

Operational NFAST Development

The results of the validation research were used to modify the validation battery for operational use. The modifications included shortening the test length, changing items with poor characteristics, revising the test instructions, and improving the graphics and format of the tests. In addition, one of the RFAST tests (the Cyclic Orientation Test) was selected for retention in the operational NFAST battery.

New ancillary materials were also developed for the operational battery. A test administration manual was drafted and a new answer sheet was designed for the NFAST. The answer sheet requests additional biographic information that the validation analyses indicated was related to successful performance in IERW.

Work Projected

Preoperational NFAST Validation

The preparation and revision of the report documenting the NFAST validation research will be completed by December 1989. Submission of this report to ARIARDA will complete the scheduled activities on this project.

Operational NFAST Development

A pretest of the operational battery, including the test retained from the RFAST, will be conducted with approximately 200 entering IERW students. The pretest data will be used to evaluate the modifications that were made to the validation battery prior to implementing the NFAST. In addition, a scoring manual and an NFAST information pamphlet will be prepared. Preparation of the operational materials will be completed in January 1990.

NFAST Implementation

When the NFAST pretesting has been completed, the operational batteries and ancillary materials will be delivered to the U.S. Army Soldier Support Center for review, reproduction, and implementation. After the NFAST is in operational use, follow-on research will be conducted to ensure that applicant performance on the test batteries is within acceptable limits, that administrative procedures are being followed, and that the selection criteria are valid. Depending on the results of the follow-on research, a second validation investigation will be conducted, if necessary, using an unrestricted sample (i.e., not already selected for flight training) of IERW applicants.

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DEVELOPMENT OF A PEER COMPARISON PROGRAM

Dr. D. Michael McAnulty, Project Director

Background

This project was initiated to assist the School Secretary, U.S. Army Aviation Center, Fort Rucker, Alabama, in developing an algorithm to select course honor graduates based on the "whole person" concept. The School Secretary wanted to augment the academic grade criterion used to select honor graduates in the Aviation Officer Advanced Course (AVNOAC), a 5-month training course for captains and promotable first lieutenants. The two purposes of the augmented program are (a) to motivate students to maximize their military and academic efforts during the course and (b) to identify students who have high potential as Army aviation officers at an early stage of their careers.

Specifically, the School Secretary was interested in using peer assessments by the AVNOAC students as a component in the honor graduate selection algorithm. The peer assessments were to evaluate aspects of the students' performance that were not reflected in their academic scores. Instructor ratings were not considered as a criterion component because of the limited interaction between the school cadre and the students.

Research Objectives

Following a review of the peer assessment literature and the AVNOAC syllabus, a peer comparison (PC) methodology was proposed for use in the AVNOAC. The School Secretary agreed to support the following research activities:

- identify the most important military qualities that can be assessed by peers during the AVNOAC,
- develop the PC instruments and procedures for use in the AVNOAC, and
- evaluate the PC technique prior to its implementation.

Research Approach

The research approach was divided into three phases that correspond to the research objectives. During Phase 1, a military qualities survey was administered to identify the most important qualities that can be assessed by peers during the AVNOAC. The survey asked senior aviation officers to rate a list of primary military qualities as potential dimensions for evaluating student performance and for identifying students with high career potential. The survey data provided the information needed to develop the PC instruments.

During Phase 2, three project assessment instruments were developed: the PC form to be completed by the class members to evaluate their peers, a faculty advisor rating (FAR) form to be completed by each class member's training officer, and a student critique to be completed by the students to evaluate the PC instruments and procedures.

During Phase 3, the PC technique was administered on an experimental basis to two AVNOAC classes and evaluated for its potential utility as an operational component of the honor graduate algorithm.

Work Completed

Phase 1: Military Qualities Survey

Following a search of the literature and a review of current Army student evaluation dimensions, definitions of 14 primary military qualities (e.g., adaptability, initiative, judgment, leadership, and responsibility) were compiled for evaluation by senior aviation officers. Several important military qualities were excluded from the survey because they are evaluated by academic scores or are unlikely to be demonstrated during the AVNOAC. Sixteen senior Army aviation officers were asked to rate each quality on the following four scales:

- importance to the performance of captains,
- importance to the performance of senior officers,
- probability of demonstration during the AVNOAC, and
- degree of overlap with the other qualities.

Eleven surveys were completed and returned. Three of the qualities (leadership, judgment, and responsibility) had consistently high ratings and were selected as PC dimensions. Seven of the qualities were clearly perceived as being inappropriate PC dimensions. Appearance and cooperation were selected from the remaining four qualities as two additional PC dimensions.

Phase 2: Form Development

Three research forms were developed for use in this project. The PC form was developed from (a) the results of the military qualities survey, (b) a combination of the peer nomination and peer ranking techniques (e.g., Kane & Lawler, 1978), and (c) the psychophysical method of paired comparisons (Engen, 1971). On the PC form, each section member (classes are divided into two sections) is required to nominate and rank order five peers on the basis of their potential as Army aviation officers. The section member then makes paired comparisons of the nominees on the five military qualities that were selected from the military qualities survey.

PC scores are computed for each peer by first summing the rank score (five points for first rank, four points for second rank, ..., one point for fifth rank) from each nominating section member. The summed rank scores are then added to the number of favorable comparisons the peer received on each military quality. Finally, the total is divided by the maximum possible score to enable direct comparisons between sections with unequal numbers of students. The PC scores can range from 0.0 (no nominations) to 1.0 (ranked first by all section members and always favorably compared with the other nominees). Because each section member nominates five peers out of approximately 50 students, a PC score greater than .20 probably represents a consensus among the section members that the student has high potential as an Army aviation officer.

A FAR form was developed to obtain independent evaluations of the students' potential as Army aviation officers. Each AVNOAC faculty advisor usually supervises six or seven students. On the FAR, the advisors estimate the officer potential of their students by assigning them percentile ranks in an average group of 100 captains.

Finally, a student critique form was developed to ascertain student attitudes toward the peer comparison program. The students are asked to rate the fairness, utility, aversiveness, and difficulty of various aspects of the program. They are also asked to express their opinions about the implementation of the program and to offer recommendations for improving the program.

Phase 3: Experimental Evaluations

First administration. Peer comparisons were collected on an experimental basis (i.e., the PC scores were not used to select honor graduates) from Sections 1 (n = 38) and 2 (n = 40) of AVNOAC 85-2 during the fourth month of training. A second set of PC ratings and the student critiques were collected from Section 1 (n = 33) and Section 2 (n = 28) at the end of the course, approximately 1 month later. The faculty advisors completed the FARs immediately after graduation. In addition, the final academic averages (AVGs) were obtained from the School Secretary's office.

The scores for the first and second data collections were highly correlated (Section 1 = .96 and Section 2 = .86), indicating the stability of the ratings over time. Because of the high correlations, the ratings from the two data collections were combined into a single PC score for each peer. The PC scores ranged from .00 to .48 in Section 1 and from .00 to .36 in Section 2. Four peers in Section 1 and three peers in Section 2 received PC scores greater than .20. A majority of the PC scores in both sections were between .00 and .05. The scores indicate a consensus among the members of the class in identifying peers with the highest potential as aviation officers.

For Sections 1 and 2, respectively, the PC correlations are .45 and .33 with the FAR, and .55 and .30 with the AVG. These moderate correlations show an expected relationship between evaluations of the same individuals but indicate that the PC score is measuring a unique perspective of the class members. The correlations between the FAR and AVG are .76 and .59 in Sections 1 and 2, respectively. The higher FAR-AVG correlations probably indicate that the faculty advisors depended on the academic average as a primary source of information in making their ratings.

Finally, the responses to the PC critique were tabulated. The overall reaction of the class members to the PC program was negative: a majority indicated that the PC was very biased, slightly or not at all useful, and slightly or not at all predictive of future performance. Furthermore, 72% of the respondents were either very or extremely unfavorable toward implementing the program. The responses to the other critique items reflected combinations of positive, negative, and neutral attitudes, without any attitude representing a majority opinion.

The results of the first administration indicated that the PC technique was a potentially useful procedure for identifying the class members with the highest potential as Army aviation officers, although the students were critical of its use. There were, however, several problems with the first administration. First, the students were not advised about the PC program before the experimental administration. Second, a surreptitious attempt by the class leaders to evaluate the section members was discovered just before the second data collection. Both problems may have affected the students' attitudes about class evaluations. Finally, the period of time between the first and second PC administrations was too short to evaluate the stability of the peer assessments.

Second administration. The second experimental administration was designed as a replication of the first administration, with the following changes:

- students were advised in advance of the research,
- other nonacademic evaluations were prohibited,
- 3 months elapsed between the initial and final data collection,
- the military quality definitions were modified slightly,
- the order of presentation of the military qualities and nominee pairs was completely counterbalanced, and
- a new roster coding system was instituted to protect student privacy.

Usable PC ratings were collected from 48 students in each section of AVNOAC 86-1 during the second month of training. At the end of the course, 47 students in Section 1 and 44 students in Section 2 completed usable PC ratings and student critiques. After graduation, FARs were completed by most of the faculty advisors and the AVGs were collected from the School Secretary's office.

Two types of reliability coefficients were computed on the AVNOAC 86-1 ratings. First, the correlations between the initial and final ratings are .79 in Section 1 and .93 in Section 2, indicating the stability of the ratings across a period of approximately 3 months. Second, split-half (odd-even) correlations for each data collection for each section were computed to evaluate the internal consistency of the ratings. The correlations are .71 and .76 for Section 1 and .93 for both data collections for Section 2. The reliability coefficients are acceptable in all cases, although they are substantially higher in Section 2. Because of the high correlations, the ratings from the two data collections were combined into a single PC score for each peer in each section.

The PC scores ranged from .00 to .24 in Section 1 and from .00 to .47 in Section 2. Four peers in Section 1 and two peers in Section 2 received PC scores greater than .20. The majority of the PC scores in both sections were between .00 and .05. The scores indicate a consensus among the members of Section 2 in identifying the two peers (PCs = .42 and .47) with the highest potential as aviation officers. The PC scores in Section 1 also distinguish the peers having the highest potential, even though the PC scores are much lower. The lower scores could be an artifact of the methodology if there are more than five peers with high potential who are not substantially different from each other.

The PC scores were then correlated with the FARs and AVGs. For Sections 1 and 2, respectively, the PC correlations are .02 and .30 with the FAR, and .24 and .27 with the AVG. These correlations indicate that the PC score, compared to the FAR and AVG, is measuring a different aspect of the class members' performance. The .02 correlation between the FAR and PC in Section 1 is partially attributable to the highly skewed distribution of FARs. The correlations between the FAR and AVG are .53 in both sections. The FAR-AVG correlations probably indicate that the faculty advisors used the academic average as a primary source of rating information.

Finally, the PC critique responses from class 86-1 were negative overall, but not as negative as those from class 85-2. A majority of the 86-1 respondents indicated that the PC was either slightly or not at all useful for selecting AVNOAC honor graduates; the respondents were approximately evenly divided on the issues of PC fairness, bias, and predictability of future Army performance. Ratings of the adequacy of definitions and the difficulty of nominating, ranking, and comparing peers were very similar to the results from class 85-2. Despite the slight positive shift in attitude toward the PC program, 69% of the respondents were still either very or extremely unfavorable toward any potential implementation of the program.

A report (McAnulty, 1989) that describes the development and evaluation of the PC procedure was written and submitted to ARIARDA with the following conclusions and recommendations. The results of the AVNOAC classes 85-2 and 86-1 data collections indicate that the PC technique is a potentially useful procedure for identifying the peers with the highest potential as Army aviation officers, at least in terms of the reliability of the ratings. There was a consensus about which peers had the highest potential, and the ratings were generally consistent over a 3-month data collection interval. However, longitudinal research is required to determine the validity of the PC technique for predicting future performance. The students in both AVNOAC classes found the rating procedure to be aversive and were unfavorable toward implementing the PC technique.

Work Projected

Submission of the report completed all activities on this project.

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ARMY AVIATION AMMUNITION AND GUNNERY SURVEY

Dr. D. Michael McAnulty, Project Director

Background

In January 1987, the Department of Gunnery and Flight Systems (DGFS) at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama, requested that the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) provide research support in conducting an ammunition and gunnery survey of active Army (AA) and National Guard (NG) aviation units. ARIARDA agreed to assist in designing and pretesting the survey; to develop the data entry, verification, and analysis programs; to conduct the required data analyses; and to prepare briefing materials and technical reports as required. All other project activities (e.g., administrative coordination, pretesting, data collection, data entry) were to remain the responsibility of the DGFS Study Group.

Problem

The survey research was designed to provide an empirical data base for addressing three major problem areas. First, the increasing cost of ammunition and the competition for Department of Defense funds have created pressure to reduce the annual allocation of ammunition for Army aviation gunnery training. The research was intended to document the current utilization of ammunition in aviation gunnery training, to evaluate the success of the gunnery training, and to compile estimates of the amount of ammunition required to maintain specified Standards in Training Commission (STRAC) readiness conditions. In addition to justifying the ammunition allocations, the resulting data base was used by DGFS to develop a new gunnery training manual.

The second major problem is the lack of adequate ranges for training and qualifying unit aviators. Many units complain that the available ranges lack the targetry, scoring devices, and space required for effective training. Furthermore, limited access to the ranges inhibits the gunnery training and makes it difficult to maintain the required readiness conditions. The research was intended to document the availability, type, and utility of gunnery ranges currently in use by Army aviation units.

The final major problem is the lack of empirical data about the utility of flight simulators for weapon systems training. Theoretically, flight simulators can reduce the effects of the first two problems. That is, weapon training can be conducted without ranges and without incurring ammunition costs. However, there are no data that identify the tasks that can be trained effectively in simulators, the amount of training that is most cost-effective, or the extent that flight simulator training can offset the need for weapon firing in the aircraft.

The latter problem is compounded by the single configuration of the AH-1 attack helicopter flight and weapons simulator (FWS) that is used by unit aviators who fly different configurations of AH-1 attack helicopters (e.g., AH-1G, AH-1S Modified, and AH-1S Production models). The FWS is configured like the AH-1S Fully Modernized helicopter. The survey research was designed to collect information about the utilization of flight simulators for conducting aerial weapon training.

Research Methodology

In January 1987, the Commanding General of the USAAVNC directed that a survey of field unit aviators and aviation unit commanders be conducted to compile the research data required to meet the following project objectives:

- describe the current attack aviation force,
- formulate an accurate ammunition procurement request,
- evaluate the training value of flight simulators for aerial gunnery, and
- support revisions to the Army's aerial gunnery training programs.

Survey Development

Survey development began with a review of the relevant literature, the then current aerial gunnery training manual (Field Manual (FM) 1-140), and a previous STRAC questionnaire (1987). The DGFS Study Group then delineated the Essential Elements of Analysis (EEA) for the survey. Approximately 100 preliminary survey items were drafted in the following ten topics covered by the EEA:

- personal data about the respondent,
- military experience of the respondent,
- flight experience of the respondent,
- present duty assignment of the respondent,

- suitability of current gunnery training publications,
- weapon systems on the aviator's primary aircraft,
- ammunition allocated and fired during the 1987 training year,
- utilization of gunnery range facilities,
- utility of flight simulators for gunnery training and qualification, and
- door gunnery training.

The preliminary survey items were administered to approximately 50 attack helicopter aviators by DGFS personnel. The pretest results were used to produce the operational survey, which was divided into two forms: Form A for the unit aviators and Form B for the unit commanders. Many of the items on the two forms are similar in content, but the unit aviators were instructed to respond to the items with respect to themselves and the unit commanders were instructed to respond to the items with respect to the entire unit, except for their personal data and experience. Anacapa Sciences personnel edited the final versions of the survey forms and prepared the required ancillary materials (e.g., letters of instruction). Subsequently, the surveys were approved for use by the U.S. Army Soldier Support Center and reproduced for administration by DGFS.

Form A contains 68 items divided into 9 of the 10 topic areas listed previously; no questions are posed to the unit aviators about door gunnery. Form B contains 78 items divided into all 10 topic areas. The surveys are much more comprehensive than the number of items indicates. That is, many items have multiple sections or require a succession of responses. Although all the items do not apply to all the respondents, there are 472 codable responses on Form A and 644 codable responses on Form B. In addition, both forms have several open-ended response items.

Survey Data Collection

During August 1987, DGFS personnel distributed 362 commander forms and 1996 aviator forms to the AA and NG units. The majority of the surveys were administered by installation points of contact. The remainder of the surveys were administered by DGFS personnel during visits to field units.

ARIARDA personnel developed computer programs to enter and verify the survey data. DGFS and Anacapa personnel entered and verified the survey responses as the forms were received from the aviators and commanders. Data collection was terminated on 19 November 1987. At that time, 127 (35%) usable unit commander forms and 810 (41%) usable unit aviator forms had been completed and returned to DGFS for processing. In addition, 35 commander and 184 aviator forms were returned either unused or incomplete. The percentage of NG respondents was 36.2% for the unit commanders and 31.9% for the aviators.

Several meetings were held with DGFS personnel to enumerate the most important research issues and to identify the subset of survey items that address those issues. Subsequently, ARIARDA and Anacapa personnel developed a statistical approach, wrote the required computer programs, and analyzed the data. The AA and NG data were analyzed separately because of the major differences in unit mission, types of aircraft flown, and training resources and standards.

Results and Conclusions

The return rates of usable survey forms were judged to provide a reliable data base for analysis, although there were limitations on the number of subsample analyses that could be conducted. The results of the survey data analyses were documented in two reports (McAnulty, Cross, & DeRoush, 1989; McAnulty & DeRoush, 1988) and are summarized in the seven general conclusions discussed in the following paragraphs.

1. The AA respondents are, on the average, relatively young and inexperienced in their occupational specialty. The NG aviators are older and more experienced than their AA counterparts and, therefore, may be able to maintain their skills at acceptable levels with less training resources. The AA and NG commanders have approximately equal experience levels.

2. The average AA aviator flew slightly more than the minimum number of hours required to maintain his flight skills in Fiscal Year 1987 (FY87), but fired less than the authorized number of ammunition rounds. The average NG aviator flew fewer hours and fired less ammunition than his AA counterpart.

3. A substantial number of AA and NG units were unable to meet their training readiness standards with the resources available to them in FY87. The lack of sufficient ammunition was the most frequently cited reason for not meeting the standards, but other resource limitations were also cited.

4. Gunnery ranges were not readily available to many units or did not have adequate scoring methods. Very few of the ranges were designed specifically for aviation gunnery, and most were shared with other branches. These problems were especially critical for the NG units.

5. The AA aviators used flight simulators for gunnery training to a moderate extent (a median of 10 hours) during FY87. Very few NG units had access to simulators, so their simulator usage data were not analyzed. The AA respondents perceived the simulators to have utility for some types of training tasks but not for other types. Specifically, tasks that were highly dependent on the simulator visual system generally received lower ratings. The lack of physical fidelity between the AH-1 models and the FWS was not judged to impair training on most types of tasks. AH-64 aviators rated the training value of the AH-64 Combat Mission Simulator higher than the AH-1 aviators rated the FWS on 7 of 12 types of training.

6. The respondents indicated a desire for standardized gunnery tables to support the development of unit training programs. The data obtained from the survey respondents constitute a source of information for revising the FM 1-140 tables.

7. The estimates of ammunition requirements indicate that the current STRAC authorizations approximate the minimum number of rounds needed to qualify and sustain the average aviator's gunnery skills. The estimates are supported by the FY87 data on the number of rounds fired (less than authorized) and the percentage of units that did not meet their training readiness standards.

A large part of the survey information about ammunition requirements and training utility is based on subjective opinions rather than objective data. Although the survey data provide valuable information, further research that includes longitudinal surveys and empirical experiments is needed to determine the amount, frequency, and type of training required to ensure that AA and NG attack helicopter units are capable of accomplishing their missions.

Work Projected

All the scheduled project activities have been completed and no further work is anticipated on this project.

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UTILIZATION/EFFECTIVENESS OF FLIGHT SIMULATORS FOR AVIATION UNIT TRAINING

Dr. George L. Kaempf, Project Director

Background

Work under this research area was conducted in response to two taskings by the Directorate of Training and Doctrine (DOTD) to the Army Research Institute Aviation Research and Development Activity (ARIARDA) at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama. One tasking originated at the USAAVNC and the other originated at the Department of the Army (DA). The taskings have been discussed in detail previously (see Cross & Gainer, 1987; Kaempf, 1988; Kaempf & Blackwell, 1988; Kaempf, Cross, & Blackwell, 1989). Therefore, only a brief review of the taskings is presented in this report.

USAAVNC Tasking

The Army Audit Agency (AAA) audited the Army's Synthetic Flight Training System (SFTS) twice, first in 1981 and again in 1984. Reports of these audits (U.S. Army Audit Agency, 1982, 1985) stated that, although flight simulators had reduced training costs and improved training at the USAAVNC, the Army had not determined the effects that the employment of flight simulators may have on training in operational aviation units. Both reports admonished the Army for the manner in which operational tests had been conducted on the SFTS and concluded that the Army had not adequately quantified the return on its investment in flight simulators procured for aviation unit training.

In response to the audits, the USAAVNC tasked DOTD to initiate research that addressed the issues raised by AAA. In 1985, DOTD formally tasked ARIARDA to plan and conduct research to answer such questions as:

- What tasks can best be trained in flight simulators?
- What rate of practice in flight simulators best enables aviators to maintain proficiency?
- How can flight simulators be used to sustain proficiency on skills that are not routinely practiced in the aircraft?
- What effect does simulated gunnery training, as a substitute for live-fire training, have on aviator proficiency and unit readiness?

As a result of the tasking from USAAVNC, ARIARDA and Anacapa initiated three research projects in the AH-1F Flight and Weapons Simulator (FWS): backward transfer and skill acquisition in the FWS, transfer of training in the FWS for emergency touchdown maneuvers (ETMs), and transfer of training in the FWS for gunnery skills. The first two projects have been completed; the third project was planned but was eventually subsumed under the work conducted for the DA tasking.

DA Tasking

In 1986, the Office of the Deputy Chief of Staff for Operations at DA reviewed the issues concerning the development of flight simulation training programs and the fielding of flight simulators. DA determined that training effectiveness analyses should be conducted for each of the Army's flight simulation systems. DA intended the analyses to serve as the basis for developing effective training strategies and programs.

Research plan. In June 1986, DA tasked the Training and Doctrine Command (TRADOC) to develop and implement, with the assistance of ARIARDA, post-fielding training effectiveness analyses (TEAs) of the Army's visual flight simulator systems. ARIARDA and Anacapa developed a research plan (Army Research Institute, 1986) that addressed the utilization of flight simulators in operational environments. In December 1986, ARIARDA submitted the research plan to TRADOC. In June 1987, TRADOC approved the TEA research plan and authorized ARIARDA to implement the research.

Gunnery training focus. Concurrent with the TEA tasking, the Department of Gunnery and Flight Systems (DGFS) at the USAAVNC revised the helicopter gunnery training manual (FM 1-140). The revised manual (designated TC 1-140) specifies the gunnery training requirements and performance standards for aviation units. Before issuing the revised manual, however, DGFS requested that ARIARDA incorporate into the TEAs an analysis of the crew gunnery training programs proposed in TC 1-140. The objectives of the analysis are (a) to determine the extent to which simulators can be used to train crew gunnery tasks effectively in aviation units and (b) to determine the amount of resources required to support crew gunnery training programs.

In response to the request from DGFS, ARIARDA agreed to focus the TEA program on the effectiveness of flight simulators for training gunnery tasks in attack helicopter aviation units. ARIARDA and Anacapa planned and initiated three research projects for gunnery tasks: TEA of the FWS for Conducting Gunnery Training, TEA of the AH-64A Combat Mission Simulator (CMS) for Conducting Crew Gunnery Initial Qualification Training, and TEA of the CMS for Conducting Crew Gunnery Proficiency Sustainment Training.

Research Area Reorganization

During the previous contract year, the research area Utilization/Effectiveness of Flight Simulators for Aviation Unit Training comprised five projects: two projects responded to the USAAVNC tasking and three projects responded to the DA tasking. During the current contract year, Anacapa reorganized the five projects into two research areas. The three projects that address training in the AH-1F FWS remain under the present research area. The two projects that address training in the AH-64A CMS were transferred to a new research area entitled Training Effectiveness Analyses of the AH-64A CMS. The AH-64 CMS research area is described in the next section of this summary report.

Problem

The Army is making a significant investment in the development and acquisition of motion-based, visual flight simulators for its rotary wing aircraft. High fidelity simulators are viewed as cost-effective alternatives to flight training in the aircraft. Visual flight simulator systems have been developed for the AH-1F, AH-64A, CH-47D, and UH-60 helicopters. Deployment to aviation units of the AH-1F and CH-47D simulator systems has been completed; the AH-64A and UH-60 simulator systems are in advanced stages of deployment to aviation units.

The Army's primary objective for flight simulation is to provide training devices in which operational aviators may sustain their flight and tactical skills. However, little empirical data currently exist (a) to demonstrate that flight simulators effectively and efficiently provide this type of training and (b) to guide the Army in developing training programs that include an optimum mix of training conducted in the aircraft and flight simulator. Empirical data are needed to ensure that the Army receives the maximum return on its investment in flight simulators.

Research Objectives

The overall objective of this research area is to evaluate the effectiveness of the U.S. Army flight simulator systems for training operational aviators. The current research projects are designed to meet the following objectives:

- develop procedures for evaluating flight simulator training effectiveness,
- identify tasks that can be sustained effectively and efficiently in the FWS,
- determine the effectiveness of the FWS and the CMS for training crew gunnery tasks and sustaining crew gunnery proficiency in operational units,
- provide the data needed to develop training programs that comprise an optimal mix of flight simulator and aircraft flight training in aviation units, and
- identify training techniques and strategies that will enable aviators to sustain their flight and tactical skills through training in flight simulators.

Research Approach

Backward Transfer and Skill Acquisition in the FWS

Two experiments were planned for this project. The purposes of the first experiment were to determine if the AH-1F aircraft and the FWS are interchangeable training devices and to test the utility of the backward transfer paradigm. In this experiment, AH-1F instructor pilots at the USAAVNC, who were proficient in the AH-1F but unfamiliar with the FWS, were evaluated in the aircraft and the FWS on their performance of eight maneuvers, including five emergency touchdown maneuvers (ETMs). The backward transfer of skills was evaluated by comparing pilot performance in the aircraft to pilot performance in the FWS.

The purpose of the second experiment was to estimate how many practice trials were required to reach a satisfactory level of proficiency on each maneuver. In this experiment, four different groups of aviators from aviation units each received simulator training on a different set of five maneuvers. The subjects received a maximum of ten practice trials on each maneuver.

Transfer of Training in the FWS for ETMs

This project was designed to evaluate the effectiveness of the FWS for training five ETMs that aviators assigned to aviation units normally are prohibited from practicing in the aircraft. The Army granted an exception to the prohibition for this experiment. Aviation unit aviators were given checkrides in the AH-1F aircraft and in the FWS; they were then assigned to a control group or an experimental group. The control group subjects were trained to proficiency on the ETMs in the aircraft. The experimental group subjects were trained to proficiency on the ETMs in the FWS and then trained to proficiency in the aircraft. The effectiveness of the simulator training was tested by comparing the two groups on their performance during training in the aircraft.

Training Effectiveness Analysis of the FWS for Conducting Gunnery Training

This project is designed to evaluate the effectiveness of the FWS for sustaining crew gunnery skills in aviation units. Fifty current AH-1F aviators in U.S. Army, Europe (USAREUR) aviation units will be assigned to one of three groups: one control and two experimental. Each subject's initial proficiency on crew gunnery tasks will be evaluated during a pretest live-fire gunnery exercise.

Following the pretest live-fire evaluation, the subjects will enter a 13-month gunnery training program. In addition to the normal unit training, the Experimental Group 1 aviators will receive gunnery training in the FWS every month and the Experimental Group 2 aviators will receive gunnery training in the FWS every 3 months. However, aviators in both experimental groups will be restricted on the gunnery tasks that they can practice in the aircraft. The Control Group aviators will receive the unit's normal training and will not be restricted on gunnery practice in the aircraft. The effectiveness of the FWS for sustaining gunnery skills will be tested by comparing the performance of the three groups during a posttest live-fire exercise.

Work Completed

Backward Transfer and Skill Acquisition in the AH1FWS

All data collection and analyses were completed during a previous contract year, and a report was written to present the findings of the experiment. During the current contract year, Anacapa edited the report and submitted it in final format (Kaempf et al., 1989) to ARIARDA.

Transfer of Training in the AH1FWS for ETMs

All data collection and analyses were completed during a previous contract year and a report (Kaempf & Blackwell, 1988) was written to present the findings of the experiment. During the current contract year, Anacapa edited the report and submitted it to ARIARDA.

Training Effectiveness Analysis of the AH1FWS for Conducting Gunnery Training

In October 1988, USAREUR officials authorized ARIARDA to conduct the TEA of the FWS and tasked V and VII Corps to provide resources to support the experiment. Three aviation units identified 25, 13, and 12 AH-1F aviators, respectively, to serve as subjects. Because of logistical and scheduling considerations, each of the aviation units entered the experiment as its training schedule permitted and proceeded independently of the other two units.

An AH-1F Aviator Questionnaire was developed and administered to AH-1F aviators in USAREUR units. The AH-1F Aviator Questionnaire contains 44 items requesting information about personal history, flight experience, current duty assignment, experience with AH-1F weapon systems, and opinions about flight and gunnery training. The objectives of the questionnaire are to describe (a) the subjects participating in the TEA and (b) the population of AH-1F aviators from which the subjects were selected. Approximately 200 AH-1F aviators responded to the questionnaire, including the 50 TEA subjects.

Two other data collection instruments were developed for use in the TEA: the Diagnostic Gunnery Skills Test and the Postflight Debriefing Form. The Diagnostic Gunnery Skills Test comprises 32 items designed to test the subjects' knowledge of the AH-1F weapon systems and gunnery techniques. All subjects completed the test prior to their pretest live-fire exercise. The Postflight Debriefing Form comprises 16 items that document the training that the subjects receive in the aircraft in conjunction with their training in the FWS. Gunnery and tactical tasks are emphasized on the form. All subjects were required to complete a debriefing form immediately after each flight in the aircraft.

The three participating units conducted their pretest live-fire exercises in January, April, and May 1989, respectively. During the pretest live-fire exercises, each aviator was required to complete Table VII, Crew Training, and Table VIII, Crew Qualification, of TC 1-140 (U.S. Army Aviation Center, 1988). Each table comprises ten engagements accomplished from ten different firing positions. Data collectors recorded measures of target effect, total engagement time, and exposure time for each engagement.

Following the pretest live-fire exercises, Experimental Groups 1 and 2 began the TEA training program. The TEA training program was designed to sustain proficiency on specific gunnery tasks within the context of mission scenarios. During each FWS training session, the subjects planned and executed an attack mission prepared by Anacapa personnel and AH-1F standardization pilots. The attack mission differed for each FWS training session. During each training session in the FWS, a data collector recorded several performance measures, including total engagement time, target effect, flight time in each crew station, and number of rounds expended.

In August 1989, ARIARDA directed Anacapa to terminate work on the FWS TEA no later than 30 August 1989. On 28-29 August, the Anacapa Sciences Project Director briefed ARIARDA personnel about the project's status and discontinued work on the project.

Work Projected

Backward Transfer and Skill Acquisition in the AH1FWS

No further work is planned for this project. Submission of the report to ARIARDA completed all activities for this project.

Transfer of Training in the AH1FWS for ETMs

No further work is planned for this project. Submission of the report to ARIARDA completed all activities for this project.

Training Effectiveness Analysis of the AH1FWS for Conducting Gunnery Training

No further work is planned for this project by Anacapa Sciences personnel. ARIARDA personnel have assumed responsibility for continuing the data collection phase of the project.

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TRAINING EFFECTIVENESS ANALYSIS OF THE AH-64A COMBAT MISSION SIMULATOR

Dr. Richard Weeter, Project Director

Background

Five projects evaluating the effectiveness of flight simulators were originally planned under the research area entitled Utilization/Effectiveness of Flight Simulators for Aviation Unit Training (see pp.71-79). In April 1989, Anacapa reorganized these projects. The three research projects already in progress on AH-1 Flight and Weapons Simulator (FWS) issues remain under the original research area; the two projects planned to address AH-64A Combat Mission Simulator (CMS) issues were transferred into the present research area.

The two CMS projects were developed in response to a Department of the Army (DA) tasking to the Army Research Institute Aviation Research and Development Activity (ARIARDA) in 1986. Following a request from the Department of Gunnery and Flight Systems (DGFS) in 1988, the projects were modified to focus on helicopter gunnery issues. The DA tasking and the DGFS request are discussed in detail in Cross and Gainer (1987) and in Kaempf (1988). Therefore, only summaries of the DA tasking and the DGFS request are presented below.

DA Tasking

In 1986, DA tasked ARIARDA, through the Training and Doctrine Command (TRADOC), to plan and initiate post-fielding training effectiveness analyses (TEAs) of each of the Army's flight simulator systems. The TEAs were intended to investigate the utilization and training effectiveness of Army flight simulator systems in operational field units and to provide a basis for developing effective training strategies. In response to the tasking, ARIARDA and Anacapa developed a research plan comprising a series of related research projects (Army Research Institute, 1986). Each project was designed to investigate the effectiveness of a flight simulator system for training a specific set of tasks (e.g., weapons tasks, contact flight tasks, and emergency flight tasks) in an operational environment.

DGFS Request

Concurrent with the DA tasking, DGFS proposed revisions to the helicopter gunnery training manual, FM 1-140. FM 1-140 defines the training requirements and performance standards for the Army's aerial gunnery training program. The revised manual (TC 1-140) contains significant changes to the crew gunnery training requirements for AH-64 aircraft. In TC 1-140, DGFS proposes to conduct all AH-64A crew gunnery training and qualification in the CMS. That is, no live rounds would be provided for crew training and qualification. Live rounds would be expended only for training attack helicopter teams and for conducting combined arms live-fire and joint air attack team exercises. Before issuing the revised manual, however, DGFS requested that ARIARDA conduct research to evaluate the effectiveness of the FWS and the CMS for crew gunnery training and qualification.

ARIARDA agreed to focus the TEAs on the issues raised by the DGFS. Two projects were designed to investigate gunnery training in the CMS: TEA of the CMS for Conducting Crew Gunnery Initial Qualification Training and TEA of the CMS for Conducting Crew Gunnery Proficiency Sustainment Training.

Problem

The Army uses high fidelity flight simulators to augment and, in some cases, replace the training that aviators receive in aircraft. The Synthetic Flight Training System (SFTS) program is viewed as a cost-effective means of acquiring flight skills. In TC 1-140, DGFS proposes that flight simulators may also be an effective alternative to live-fire training in the aircraft for both the acquisition and sustainment of crew gunnery skills.

However, there is little empirical data to demonstrate the effectiveness of flight simulators in augmenting training. Empirical data are required to demonstrate that flight simulators can effectively train and sustain flight or tactical skills. Furthermore, empirical data are required to provide guidelines for establishing an optimal combination of aircraft and simulator training for specific tasks such as gunnery.

Research Objectives

The research in this area is designed to meet three major objectives:

- determine the effectiveness of the CMS for the acquisition of crew gunnery skills,
- determine the effectiveness of the CMS for the sustainment of crew gunnery skills, and
- provide data to help establish an optimum combination of aircraft and flight simulator training for the acquisition and sustainment of crew gunnery skills.

Research Approach

Initial Qualification Project

The initial qualification project is designed to evaluate the training effectiveness of the CMS for the acquisition of crew gunnery skills. Novice crews from the AH-64A Apache Training Brigade (ATB) will be assigned to either a control or an experimental group. The control group will receive the normal ATB flight and gunnery training in the AH-64A. The experimental group will conduct their flight training in the AH-64A and their gunnery training in the CMS. The effectiveness of the two training programs will be tested by comparing the crews' performance during a live-fire gunnery exercise following an 8-week training period.

Proficiency Sustainment Project

The proficiency sustainment project is designed to evaluate the effectiveness of the CMS for sustaining gunnery skills for 1 year without live-fire practice. Fully qualified AH-64A crews from the 6th Calvary Brigade - Air Combat (CBAC) will be assigned to either a control group or one of two experimental groups. The crews' baseline gunnery skills will be measured during a pretest live-fire gunnery exercise. All CMS and aircraft training received by each group will be controlled for 1 year after the pretest live-fire gunnery exercise.

The control group will receive the normal program of instruction in both the CMS and the aircraft throughout the 1-year test period. Experimental Group One will also receive the normal program of instruction in the CMS, but will receive additional gunnery-specific training in the aircraft (dry-fire on the gunnery range) during the test period. Experimental Group Two will receive the normal training in the aircraft and additional gunnery-specific training in the CMS during the test period. The amount of gunnery training received in addition to the normal training will be equated for Experimental Groups One and Two.

After 1 year, the crews' gunnery skills will be evaluated during a posttest live-fire gunnery exercise. The effectiveness of the CMS will be evaluated by (a) comparing performance between the pretest exercise and the posttest exercise and (b) comparing the performance of the three groups during the posttest exercise.

Work Completed

Initial Qualification Project

Coordination problems with the ATB have delayed the initiation of this project. During the current contract year, no research was conducted on initial gunnery qualification in the CMS.

Proficiency Sustainment Project

In April 1989, baseline live-fire exercise data were collected at the Dalton-Henson Multi-Purpose Range Complex at Fort Hood, Texas. At that time, the 6th CBAC could assign only 15 crews to the project because of anticipated personnel turnover. Consequently, baseline gunnery evaluations were scheduled for additional 6th CBAC crews during the next live-fire exercise in August.

In August 1989, baseline live-fire data were collected from an additional 12 crews, but 4 of the crews tested in April were no longer able to participate in the research. At the close of the contract year, there were 9 crews in the control group, 8 crews in Experimental Group One, and 6 crews in Experimental Group Two. During September, data were collected during the first of 10 scheduled gunnery-specific training sessions in the CMS.

Work Projected

Initial Qualification Project

During the next contract year, project personnel will meet with the ATB to determine if ATB will support the initial qualification research.

Proficiency Sustainment Project

During the next contract year, all experimental training sessions and data collection activities for this project will be completed. During the training period, project personnel will monitor (a) the type and amount of aircraft and simulator training all crews receive, (b) the number of dry-fire iterations that the crews in Experimental Group One receive, and (c) the remaining nine experimental gunnery-specific training sessions in the CMS.

Data collection during the posttest live-fire exercise for aviators who were pretested in April 1989 is scheduled for March 1990. The posttest live-fire exercise for aviators who began the project in August 1989 is scheduled for August 1990. Following the August 1990 live-fire exercise, the data will be analyzed and a draft report will be prepared. The draft report will be edited and submitted to ARIARDA early in the following contract year.

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EFFECTIVENESS OF AIRNET IN TRAINING COLLECTIVE TASKS

Dr. Beth W. Thomas, Project Director

Background

Recent assessments by the Directorate of Combat Developments (1982, 1983, 1986) at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama, identified several aviation training deficiencies, primarily in training collective or mission tasks. The training deficiencies identified in the Battlefield Development Plan (1986) include air-to-air operations, anti-armor operations, sustained aviation operations, air assault operations, suppression of enemy air defense, special operations missions, aerial reconnaissance, combat maneuvers, search and rescue operations, target acquisition and handover, and aircraft survivability. Currently, the deficient tasks are not trained effectively in helicopters because of several factors; these factors include a lack of threat interaction, a lack of combined arms/joint training, a lack of resources (e.g., flight hours, missiles), and safety concerns.

The current constraints on training in the aircraft are likely to inhibit Army aviation training in the future. Therefore, there is a need to evaluate simulation as a supplement to institutional and unit aviation training. The Directorate of Training and Doctrine (DOTD) began work on the development and acquisition of an Aviation Combined Arms Team Trainer in 1983, but the cost of building a prototype device became so prohibitive that the program was discontinued in 1985.

DOTD then began to investigate alternatives to developing a completely new aviation simulator. At that time, the Defense Advanced Research Projects Agency (DARPA) was sponsoring a research and development program on low cost, low fidelity simulation networking (SIMNET). In SIMNET, several simulators at the same location are networked to allow individual crews to interact with one another on the same data base. SIMNET simulates only ground force vehicles, the M1 tank and the M2/3 Bradley fighting vehicle. The cost of the networked system is kept low by including only the systems in the vehicle that are considered mission essential.

In 1987, USAAVNC established a memorandum of understanding with DARPA for the development of an aviation counterpart to SIMNET to be called AIRNET. The AIRNET device is to serve as the proof-of-concept of networking for aviation purposes. The device is to be developed in three phases: Fully Reconfigurable Experimental Device (FRED), Generic, and 60% Solution. The operational device will be called the Aviation Combined Arms Tactical Trainer (AVCATT).

On 16 June 1988, DOTD requested that the Army Research Institute Aviation Research and Development Activity (ARIARDA) evaluate the ability of the AIRNET device to support the training of Army Training and Evaluation Program/ Mission Training Plan (ARTEP/MTP) tasks (ARTEP, 1988). Of particular importance were the tasks that would potentially reduce the deficiencies identified in the Battlefield Development Plan. In addition, ARIARDA was asked to provide information about changes that are required to accommodate the mission tasks that cannot be performed in the device. Finally, DOTD requested that evaluations be conducted at each phase of development to determine how much fidelity is necessary and sufficient to support mission training. In September 1988, Anacapa Sciences began developing a research plan to evaluate the AIRNET device.

Research Objectives

The general objectives of this research are to evaluate the effectiveness of the AIRNET device for training collective ARTEP/MTP tasks to reduce the deficiencies identified in the Battlefield Development Plan and to provide input to the follow-on device, AVCATT. Therefore, the specific objectives of the research project are to identify:

- the ARTEP/MTP tasks for the Attack Helicopter Company and the Air Cavalry/Reconnaissance Troop that can be performed in the AIRNET device,
- the changes in the device that are required to accommodate the ARTEP/MTP tasks that cannot be performed in AIRNET,
- the training deficiencies listed in the Battlefield Development Plan (1986) that may be addressed by the AIRNET device,and
- the mission tasks in the Aeroscout Observer course that can be trained effectively in the AIRNET device.

Research Approach

Separate evaluations will be conducted for each phase in the development of the AIRNET device. In the first evaluation, aviation test pilots and instructor pilots (IPs) will "fly" in the FRED to determine its capability for performing basic flight maneuvers. The comments and recommendations of the pilots and IPs will be used to upgrade the FRED aeromodel for use in the Generic device.

The evaluation of the Generic device will be conducted in three steps. First, test pilots and IPs will fly in the Generic device to evaluate its capability for performing basic flight maneuvers. After any necessary corrections are made to the aeromodel, a formal evaluation will be conducted to determine if the Aircrew Training Manual (ATM) and ARTEP/MTP tasks can be performed in the Generic device. During this evaluation, aviation unit aviators will be trained to operate the Generic device; they will then be required to conduct combined scout/attack helicopter missions against enemy threat vehicles.

At least four types of performance data will be collected and evaluated: automated system performance measures, ratings of task performance, questionnaire data about mission task performance, and reliability, availability, and maintainability (RAM) data. The results of the formal evaluation with operational pilots will be used to modify the Generic device.

Finally, a transfer-of-training investigation will be conducted with Aeroscout Observer (AO) trainees. Some AO trainees will receive mission training in the aircraft and other AO trainees will receive mission training in the Generic AIRNET device. Differences in the effectiveness of the training groups will be determined by comparing their performance of mission tasks in the OH-58 aircraft. The results of this evaluation will be used to determine the potential utility of AIRNET for enhancing institutional training.

The evaluation of the 60% Solution AIRNET device will be similar to the Generic AIRNET evaluation. First, test pilots and IPs will fly in the device to evaluate the capability of the aeromodel for performing the basic flight maneuvers. If corrections are required, they will be made prior to the conduct of the ARTEP/MTP evaluation. During the formal evaluation, operational unit aviators will be trained to operate the device and evaluated while they conduct team training exercises against an automated enemy threat. At least four types of performance data will be collected and evaluated: automated system performance measure, subjective ratings of task performance, questionnaire data about mission task performance, and RAM data. If required, additional performance measures will be developed specifically for the 60% Solution evaluation. The results of the evaluation of the 60% Solution AIRNET device will be used to produce the AVCATT prototype device.

Work Completed

The evaluation of the FRED was conducted during November and December, 1988. Four unit IPs and three Directorate of Evaluation and Standardization IPs served as subject matter experts in this evaluation. The flight characteristics of the device were so unlike any helicopter that all individual flight tasks were virtually impossible to perform within acceptable standards. To correct these obvious problems, two pilots from the Aviation Development Test Activity (ADTA) were requested to evaluate the aeromodel of the AIRNET device. The ADTA test pilots identified the minimum changes in the flight and handling characteristics needed to allow flight. The comments from the IPs and ADTA test pilots were submitted to DOTD. The recommended changes and other planned additions were made in developing the Generic AIRNET device.

Prior to the ARIARDA evaluation on the Generic AIRNET device, the ADTA test pilots were asked to evaluate the new flight aeromodel. The pilots provided a report suggesting further changes that were necessary to decrease the workload required to fly the device. This information was forwarded to DOTD and the changes to the aeromodel were made within the next month.

The Directorate of Combat Developments developed scenarios that incorporated the ARTEP/MTP tasks in a logically, tactically, and doctrinally correct manner. The scenarios were adapted to the constraints of the AIRNET terrain. With the exception of ground tasks (e.g., preflight checks) and the flight tasks concerning Nuclear, Biological, and Chemical (NBC) warfare, all of the ARTEP/MTP mission tasks for the Attack Helicopter Company and Air Cavalry Reconnaissance Troop were evaluated during the formal evaluation. Many ground tasks were performed in preparation for the mission (e.g., company commander briefs the mission), but were not emphasized in the investigation.

Rating scales were developed for each mission task for both scout and attack crews. The scales were evaluated by subject matter experts and modifications were made where necessary to clarify the criteria for successful completion of the mission tasks. Raters were then trained to use the scales. Interobserver reliability was 1.0 for each mission task for both scout and attack rating teams.

Mission task and technical performance questionnaires were developed to be administered to the individuals participating in the evaluation. Short versions of the questionnaire (Form A) were administered prior to and following the collective evaluation of the Generic device. The longer questionnaire (Form B) included questions on simulator sickness, negative habit transfer, and relative training value of AIRNET; Form B was administered on the final day of the evaluation.

From 21 July to 7 September 1989, one operational attack helicopter unit participated in the formal evaluation of the Generic AIRNET device. The unit was divided into two teams: one team was composed of two scout and two attack helicopters; the other team was composed of one scout and two attack helicopters. The investigation included training on the operation of the device, a pretest of performance on the individual ATM tasks, an evaluation of performance on collective mission tasks, and a posttest of performance on the individual ATM tasks. In addition, the reliability, availability, and maintainability of the system was evaluated by a RAM engineer from DOTD.

A preliminary summary report of the evaluation was requested by DOTD so that recommended changes could be integrated into the design of the 60% Solution AIRNET device. A draft preliminary report was submitted to ARIARDA in September 1989. Following a review by ARIARDA, the draft preliminary summary report was revised and submitted in final form on 3 October 1989 (Thomas, 1989). The report documents several deficiencies in the Generic device. In particular, corrections to the aeromodel are still required to enable the aviators to perform the mission tasks. The reliability of the device needs to be improved; the maintenance required to operate the devices is excessive. The results indicate that networked simulators are potentially useful for conducting combined arms and joint training; however, the present version of the Generic AIRNET device does not meet the AVCATT objectives. In addition, further research is required to determine the training effectiveness of the AIRNET device for the ARTEP/MTP tasks.

Work Projected

The final report on the evaluation of the Generic AIRNET device will be prepared and submitted when all of the analyses have been completed. The final report will provide more detailed information about the results presented in the preliminary summary report and will include additional information that was not available at the time the preliminary report was written.

The training effectiveness evaluation of AIRNET for use in the AO course is scheduled for November 1989. Mission tasks trained in the device will be evaluated against performance in the aircraft. The mission tasks will be as follows: call for and adjust fires, perform actions on contact, provide spot reports, and acquire and handover targets. IPs for the AO course will conduct the training in the AIRNET device and the evaluations in the aircraft.

Anacapa and ARIARDA will also conduct an ARTEP/MTP evaluation on the AIRNET 60% Solution device when it is installed at Fort Rucker.

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DEVELOPMENT OF THE AH-64A DISPLAY SYMBOLOGY TRAINING MODULE

Dr. John W. Ruffner, Project Director

Background

The AH-64A attack helicopter is a two-crewmember aircraft designed to fly nap-of-the-earth missions to detect, engage, and destroy enemy armor during day or night and in all weather conditions. To provide this capability, the AH-64A is equipped with complex flight and weapons delivery systems. The successful operation of these systems requires that the pilot and copilot/gunner (CPG) be able to identify and interpret both visual imagery and symbolic information presented on visual displays.

The AH-64A visual display systems that provide information to the pilot and the CPG are the Pilot Night Vision System (PNVS) and the Target Acquisition and Detection System (TADS). The PNVS provides forward-looking infrared (FLIR) imagery that enables the pilot to fly the aircraft at night and during degraded visibility conditions. The TADS is used by the CPG for target search, detection, recognition, and designation. The TADS uses information from three sensors: the FLIR system, the day television viewing system, and the direct view optics system. These three sensors provide the CPG with visual information to detect and engage targets at standoff ranges during day or night operations and in adverse weather conditions. The Fire Control Symbol Generator superimposes flight and weapons symbology on the imagery displayed by the PNVS and the TADS.

The visual imagery and symbology from the PNVS and the TADS can be presented to the pilot on a 4.0 by 5.0 inch panel-mounted display or to the CPG on a 2.25 by 3.25 inch panel-mounted display. In addition, the imagery and symbology can be presented to either crewmember through the Helmet-Mounted Display (HMD), which consists of a 1 inch in diameter display attached to the helmet. The HMD is a monocular display that enables the crewmember to cross-check flight and weapons information superimposed on infrared sensor imagery while directing his attention outside the cockpit. All the displays provide the crewmember with a 30° (vertical) by 40° (horizontal) field of view.

PNVS Flight Symbology

The PNVS flight symbology set consists of 27 alphanumeric and shape coded symbols that are designed to help the crewmember fly the aircraft. Many of the computer generated symbols are adaptations of traditional electromechanical instruments and are located in fixed positions on the displays (e.g., Heading Scale, Vertical Altitude Scale). Some, however, are unique dynamic representations of spatial information that move about the displays and in or out of the viewing areas as a result of sensor orientation or changes in aircraft position (e.g., Cued Line of Sight [LOS] Reticle, Hover Position Box).

To reduce clutter and to make the symbolic information more task specific, there are four operating modes that present subsets of the 27 symbols. Symbols representing aircraft heading, airspeed, altitude, engine torque, and certain other basic flight information are provided constantly during all four modes. The hover mode adds a velocity vector and an acceleration cue to aid the pilot in maintaining a hover. Selection of the transition mode adds a horizon line to the hover mode subset and is used when changing from a hover to cruise flight. Once cruise flight has been established, selection of the cruise mode removes the velocity vector and acceleration cue from the transition mode set. To aid the pilot in returning to a chosen location or remaining over the location with a specific heading, a bob-up mode adds the velocity vector, acceleration cue, command heading, and hover position symbols to the basic flight information.

TADS Weapon Symbology

The TADS weapon symbology set consists of 17 alphanumeric and shape coded symbols. Fourteen symbols are common to both the flight and weapon symbology sets. The symbols are designed to assist the crewmember during the operation of the weapon systems. There is only one operating mode for the TADS symbology, but not all the symbols will appear on the displays at the same time. The number of symbols displayed at any given time depends on the nature of the tasks required to operate the weapons.

Training Process

To become fully qualified in the AH-64A attack helicopter, a student aviator must learn to identify and interpret the individual symbols presented on the helicopter's visual displays and to interpret the information provided by groups of symbols. During the AH-64A Aircraft Qualification Course (AQC), student aviators are taught to use the symbology through classroom lectures, videotape presentations, self-study handouts, and technical manuals containing static diagrams of the symbology. Opportunities for additional practice with the display symbology are available on three training devices: the TADS Selected Task Trainer (TSTT), the Cockpit, Weapons, and Emergency Procedures Trainer (CWEPT), and the Combat Mission Simulator (CMS).

The TSTT is a part-task trainer designed to support initial CPG qualification, CPG refresher training, and TADS skill sustainment; it provides practice only with weapon symbology. The CWEPT is a full-scale pilot and CPG procedures trainer that is used to train normal and emergency flight procedures and avionics equipment operation. The CMS is a six degree-of-freedom, motion-based simulator that provides training in combat mission scenarios during the Combat Skills phase of the AH-64 AQC and during operational aviation unit training. Both the CWEPT and the CMS provide the opportunity for practice with flight and weapon symbology.

Need

The training design features of the TSTT, CWEPT, and CMS do not include training on basic symbology identification and interpretation. Students assigned to training lessons on these devices are assumed to be familiar with flight and weapon symbology. However, TSTT, CWEPT, and CMS instructors report spending an excessive amount of time training basic symbology skills in the training devices. Furthermore, students training in the TSTT, CWEPT, or CMS typically do not have opportunities to use the AH-64A display symbology under the full range of missions, modes, weapons, system options, and system failures. A device that provides specialized training on basic symbology identification and interpretation would improve the efficiency of TSTT, CWEPT, and CMS instruction. Therefore, the Training and Doctrine Command System Manager for the AH-64A requested that the Army Research Institute Aviation Research and Development Activity (ARIARDA) develop a training module for the AH-64A flight and weapon symbology.

Project Objectives

ARIARDA established the following nine design objectives for the training module:

- designed in a self-instructional format,
- designed for use in a classroom setting,

- designed to train symbology for the full range of aircraft mission and weapon system options,
- capable of storing performance data and providing one or more performance indexes for each training exercise,
- capable of providing immediate feedback and remedial instruction when errors occur,
- suitable for both skill acquisition training in an institutional setting and skill sustainment training in an operational unit setting,
- flexible enough to allow revisions resulting from (a) design changes in the aircraft or avionics system and (b) deficiencies in the training module revealed by formal evaluation and feedback from the user,
- designed to augment rather than replace existing training devices, and
- economical to develop and operate.

Training Module Development

Researchers at Anacapa Sciences, Inc., began work on the training module in December 1986. The researchers interviewed subject matter experts (SMEs) who were knowledgeable about the AH-64A display symbology, including AH-64 AQC academic instructors, CWEPT instructors, and AH-64A instructor pilots. As a result of these interviews, performance deficiencies were identified in the following areas:

- identifying and interpreting individual symbols presented alone,
- identifying and interpreting symbols in the context of other symbols,
- interpreting the meaning of symbology movement,
- correctly associating switch actions and control movements with static or dynamic symbology, and
- alternating attention between the display symbology and the external visual scene.

The development of the symbology training module was divided into two parts. The first part, the Symbology Tutor, addresses the first three performance deficiencies by providing skill acquisition training in symbol identification and interpretation for individual symbols and small, related subsets of symbols. The second part addresses the last two deficiencies by providing training in (a) correctly associating switch actions and control movements associated with the symbology and (b) alternating attention between the symbology and real-world and infrared visual imagery. After considering the project objectives, the training module design objectives established by ARIARDA, and the capabilities and limitations of existing training devices, the researchers concluded that the most appropriate medium for the training module was computer-based instruction.

Symbology Tutor Design

The Symbology Tutor is organized into three major sections: (a) an introductory section, (b) a help system that can be accessed from anywhere in the Symbology Tutor, and (c) five self-contained lessons. The introductory section provides the student with a brief orientation to the Symbology Tutor and contains instructions on how to use the program's features. The help system provides the student with on-line assistance in using the Symbology Tutor. The help system includes (a) an overview of the entire symbology training module and the types of help available, (b) a list of the contents of the five lessons, (c) an acronym glossary, (d) a symbol dictionary, and (e) a symbology mode dictionary. The five lessons consist of tutorials and quizzes covering the following symbols: (a) position/movement, (b) attitude/altitude, (c) heading/navigation, (d) cueing/reference, and (e) weapon delivery.

Project Termination

ARIARDA directed Anacapa Sciences to terminate work on the AH-64A Display Symbology Training Module project at the end of December 1987 because of funding constraints and other project priorities. At that time, a draft version of the storyboards for the tutorials and quizzes for Lessons 1 through 5 had been completed and computer programs for the introductory section, the help system, and the tutorials and quizzes for Lessons 1 and 2 had been written. The Symbology Tutor programs were written in Microsoft QuickBASIC and were designed to run on a Zenith PC AT-compatible microcomputer equipped with one megabyte of random access memory, a hard disk with at least 2 megabytes available, an enhanced graphics adapter (EGA), and a high resolution EGA color monitor.

Report Preparation

During the current contract year, a draft project report was prepared and submitted to ARIARDA. The report describes the background, research approach, and contents of the Symbology Tutor and provides copies of the storyboards for the five lessons. Following a review by ARIARDA, the report was revised and resubmitted in final form (Ruffner, Coker, & Weeter, 1989). A floppy disc copy of the computer programs that had been developed by the project termination date was also delivered.

Work Projected

Submission of the draft report and computer programs to ARIARDA completed Anacapa's work on this project.

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DEVELOPMENT OF THE BASIC MAP INTERPRETATION AND TERRAIN ANALYSIS COURSE (MITAC)

Dr. Dudley J. Terrell, Project Director

Background

In the modern battlefield, Army aviators will fly at extremely low altitudes to avoid detection by enemy electronic sensors. To maintain obstacle clearance while remaining masked by terrain features, constant vigilance outside the cockpit must be maintained during low altitude flight. Momentary shifts of attention to displays, switches, and maps inside the cockpit must be executed rapidly and efficiently. Consequently, low altitude navigation requires superior skill in map interpretation and terrain analysis. To remain geographically oriented, a pilot must be able to glean crucial map information during brief glances inside the cockpit and to associate that information with the rapidly changing terrain outside the cockpit.

Traditional methods of low altitude navigation training have been unsatisfactory (Fineberg, Meister, & Farrell, 1978; Gainer & Sullivan, 1976; McGrath, 1976). Therefore, the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) has conducted research to address the low altitude navigation training deficiency. In 1976, Anacapa Sciences, under contract to ARIARDA, developed the Map Interpretation and Terrain Analysis Course (MITAC). The MITAC used photographic slides and motion picture films of terrain features and map segments to teach low altitude navigation skills to helicopter pilots in a classroom format. Subsequently, the course was revised to an individualized training format. Holman (1978a, 1978b) demonstrated the effectiveness of the revised course by showing that MITAC-trained student pilots and enlisted aerial observers navigated at twice the speed and with one-third the errors committed by traditionally trained aviators.

In 1979, Kelley developed 13 additional cinematic exercises to provide supplemental training in map interpretation and terrain analysis over a wider range of geographic regions and climates. Each exercise consists of a film taken from the front window of a helicopter flying a route at low altitude. The exercises include flights over various geographic regions (e.g., Kentucky, Idaho, Arizona, and Germany) with both snow-covered terrain and summer foliage. The supplemental exercises, termed the Advanced MITAC, were subsequently upgraded to a computer-based interactive videodisc format (Miles & LaPointe, 1986). Terrell (1989a) found that a significantly greater proportion of Advanced MITAC students than control (no MITAC) students performed perfectly (i.e., no deviations from the prescribed route) during the post-training navigation test.

Need

Conversion of the Advanced MITAC exercises to an interactive videodisc format resulted in an easy-to-use and effective part-task trainer. However, the material and equipment for the original "Basic" MITAC (e.g., 35-mm slides, booklets, projectors, tape players, etc.) are difficult to use and are unsuitable for computer-based training. A computer-based course that presents basic principles of map interpretation is needed to serve as a prerequisite to the Advanced MITAC and for use in the ARIARDA research program.

Project Objectives

The goal of this project is to develop a videodisc/computer-based Basic MITAC. This goal is divided into the following two project objectives:

- develop the Basic MITAC videodiscs and
- design experimental courseware for the Basic MITAC.

Development Approach

The project is divided into two phases that correspond to the two project objectives. In Phase 1, the material from the former versions of Basic MITAC will be compiled and upgraded for videodisc development. In Phase 2, instructional strategies will be planned and software written to implement the strategies. Training effectiveness evaluations of the Basic MITAC instructional strategies will be conducted as a separate project (see Training Effectiveness of Aviation Part-Task Trainers, pp. 111-117 of this report).

Work Completed

Phase 1

The development of the Basic MITAC videodiscs was completed in three stages: production, post production, and duplication. During the production stage, researchers at Anacapa Sciences composed the narrative for the Basic MITAC, selected video material to supplement the narrative, and developed a script containing the narrative and instructions for taping the narrative and video material.

During the post-production stage, Video Technics of Atlanta, Georgia, recorded the narrative on audio tape, generated the computer graphics and animation, digitized the video material, edited the video material on 3/4-inch videotape, and dubbed the audio and video on 1-inch master videotape. During the duplication stage, Optical Recording Project/3M in St. Paul, Minnesota, generated a master videodisc from the 1-inch master tape and produced videodisc copies from the master videodisc. For more information about Phase 1 of this project, see Terrell (1989b) or Terrell and Miles (1989).

Phase 2

During the current contract year, work began on developing experimental software for the Basic MITAC. Two programs were designed and developed for presenting edited information from the videodiscs. One program is for dual-screen viewing of the videodisc contents. The native monitor of a host computer is used to display program instructions and content menus, and the second monitor is used to display video from the videodisc player. The dual-screen program was loaned to the NASA Ames Research Center to use in research on emergency medical service flight navigation.

The second program is identical to the first program in content, but it uses a single switching monitor and requires a special video overlay card in the computer. The single-screen program is currently being field tested in the HS-1 Strike Rescue Course at the Naval Air Station in Jacksonville, Florida.

Work Projected

Phase 1 of this project is complete. The development of experimental courseware in Phase 2 has been postponed until a comprehensive plan of research on computer-based instructional strategies is written (see Training Effectiveness of Aviation Part-Task Trainers, pp. 141-149 of this report). Upon completion of the research plan, Basic MITAC programs will be developed to conduct experimental evaluations of several strategies and tactics of computer-based instruction.

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SURVEY OF RESEARCH IN COMPUTER-BASED INSTRUCTIONAL STRATEGIES

Dr. Dudley J. Terrell, Project Director

Background

Experimental research about computer-based instructional strategies is a recent development from two diverse areas: learning psychology and computer technology (for a review, see Eberts & Brock, 1987). Psychology became involved through the application of learning research to the design of early teaching machines (Benjamin, 1988). A growing interest in the application of computer technology to education has resulted in a new field of research and development called instructional design (Gagné, Briggs, & Wager, 1988).

Developments in computer-based instruction (CBI) promise to increase training effectiveness by capitalizing on the efficiency of the individual learning process while reducing human instructor time. Recognizing this promise, the Department of Defense has promoted CBI research through the Army Research Institute, the Army Project Manager for Training Devices, the Air Force Human Resources Laboratory, the Navy Personnel Research and Development Center, and the Naval Training Equipment Center (Dallman et al., 1983; O'Neil & Evans, 1983).

Need

Much of the current CBI research consists of individual attempts to apply recent hardware and software developments (e.g., interactive videodisc, high-speed personal computers, computer graphics) to existing training programs. Because these efforts lack a comprehensive plan for systematic experimentation, the research solves immediate training problems but fails to provide information about the general utility of training technology and the most cost-effective methods for addressing future training needs. An efficient program of CBI research requires a comprehensive plan that addresses the following questions.

- What is the best method of identifying the critical learning objectives for the proposed training program?
- What are the underlying learning principles that can be applied during the design and development of the proposed training program?
- What are the best media for presenting the proposed training program?

The U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) is developing a plan to integrate existing part-task training effectiveness research projects and to identify CBI research issues. To support the development of this comprehensive research plan, ARIARDA tasked Anacapa to conduct a survey of past research on learning principles and their application during the design of CBI programs.

Project Objectives

The goal of this project is to generate research questions that can be addressed in ARIARDA part-task training effectiveness projects. This goal is divided into the following two project objectives:

- survey the research in computer-based instructional strategies and
- organize the literature to facilitate the development of a research plan for CBI in aviation training.

Research Approach

To meet these objectives, Anacapa personnel will conduct a comprehensive survey of research on the application of learning principles to computer-based instructional design. The project is divided into three phases. In Phase 1, the published research on computer-based instructional strategies will be compiled into a data base. In Phase 2, the research results will be evaluated for their immediate applicability to computer-based instructional design. In Phase 3, a list of questions will be generated to guide future research in CBI.

Work Completed

Phase 1

A data base of CBI research literature was developed during the second contract year (Terrell, 1989a). Although this phase is formally completed, the project director has continued to review newly published literature and to enter the new information into the data base.

Phase 2

During the current contract year, a critical review of the literature was conducted to examine the empirical research support for the numerous guidelines and recommendations that have been published about CBI design strategies. The method and results of the literature review are summarized in the next two sections.

Review method. Two types of publications were selected and reviewed: reports of empirical research comparing two or more CBI strategies and published guidelines for the development of CBI. The guidelines and experiments were categorized according to whether they pertained to (a) strategies for presenting instructional material, (b) strategies for questioning and interactivity, or (c) strategies for programming response feedback and remediation procedures.

A draft report entitled "Strategies of Computer-Based Instructional Design: A Review of Guidelines and Empirical Research" was written and submitted to ARIARDA for review (Terrell, 1989b). Each section of the report begins with a list of guidelines for some aspect of instructional design and a discussion of the recommendations made by authors of the guidelines. Then, the empirical research relevant to each guideline is reviewed.

Review results. Although there are some consistencies in the literature, the guidelines and research in computer-based instructional strategies are characterized by contradictions. In some cases, authors of instructional design guidelines contradict each others' recommendations. In other cases, the empirical research contradicts the experts' recommendations. Finally, empirical research was not located to evaluate many of the recommendations.

Only 5 of the 57 guidelines reviewed are supported by empirical research. There is consistent agreement among authors and empirical evidence that CBI should present questions, corrective feedback for incorrect responses, and multiple trials for items that are answered incorrectly. Although some authors do not agree that CBI should present prelesson questions or that adaptive programming should be used to control the number of trials, the results of the empirical research indicate that these strategies are effective.

Although the experimental evidence is not sufficient to justify complete rejection, 8 of the 57 guidelines are contradicted by the results of empirical research. Empirical research generally contradicts recommendations to use graphics often, to provide increasingly informative feedback for successive errors, to train under mild speed stress, to present information before practice, to randomize the sequence of material, to present part-task training prior to whole-task training, to permit the student to control the presentation of reviews, and to program the computer to control the presentation of reviews.

Finally, 44 of the guidelines are insufficiently addressed by empirical research. For many of the guidelines, either the empirical research produced mixed results and further research is required, the empirical research is inconclusive because of inadequate experimental designs, or the empirical research simply was not located. Some of the guidelines, however, are self-evident and do not require empirical support. Other guidelines are stated in such general terms that it is impossible to evaluate their usefulness. However, some of the guidelines are very specific and their validity and generality should be determined empirically.

Phase 3

In Phase 3 of this project, guidelines were selected that most urgently require experimental investigation and might be appropriate for the ARIARDA part-task training effectiveness research. These guidelines and research issues are summarized in the following paragraphs.

Generality of guidelines. The Phase 2 survey of literature identified at least three important dimensions along which generality may vary: (a) training format (e.g., computer-based tutorials, drills, or simulations), (b) training objectives (e.g., acquisition vs. sustainment training), and (c) target population (e.g., high school or college students). Research is needed to examine the generality of instructional design guidelines across these dimensions.

Stimuli. Many of the guidelines for presenting instructional stimuli depend on the nature of the lesson content and the three dimensions of generality discussed previously. However, the effectiveness of animation and high-quality graphics should be empirically demonstrated because of the expense that may be incurred to employ them.

Interactivity. Although it is generally accepted that student-computer interactivity is a critical element in CBI, several questions remain unanswered about interactivity. The primary research issues concern the type, frequency, and placement of training questions in computer-based tutorials.

Feedback. Finally, the available research suggests that feedback for incorrect responses should be informative and should be appropriate to the type of error committed. However, relatively little is known about remediating repeated errors, feedback for correct responses, and response-feedback latency. Empirical research is required to develop valid guidelines for these issues in feedback and remediation.

Work Projected

The research issues identified in this project will be incorporated into a research plan for aviation part-task training (see Training Effectiveness of Aviation Part-Task Trainers, pp. 111-117 of this report). Unless revisions are required to the draft report (Terrell, 1989b), no further work is projected.

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TRAINING EFFECTIVENESS OF AVIATION PART-TASK TRAINERS

Dr. Dudley J. Terrell, Project Director

Background

Many aviation tasks, procedures, and skills are trainable with the use of simulators and part-task training devices (Flexman & Stark, 1987). The development of this training technology requires knowledge of the psychological principles underlying the individual learning processes and of effective instructional strategies for various kinds of performance. To acquire this knowledge, researchers at the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) have identified several operational training problems at the U.S. Army Aviation Center and have developed prototype training devices to address these problems (Miles & LaPointe, 1986a, 1986b; Ruffner, Coker, & Weeter, 1989; Terrell & Miles, 1989). The prototype training devices are designed to serve two purposes: (a) to remediate existing training deficiencies and (b) to be used in computer-based instructional strategies research at ARIARDA.

Need

The development of prototype devices for training research is an evolutionary process. Preliminary task analyses, subject matter expert advice, and existing research are used to design the first systems. At several stages in the design process, the devices must be subjected to training effectiveness analyses. The results of these analyses are used to improve the design of the training system. Experiments designed to evaluate the effectiveness of various instructional strategies provide the basis for making recommendations about the optimal use of the training systems.

Research Objectives

The general purpose of this research area is to evaluate the effectiveness of prototype training devices and instructional strategies being developed at ARIARDA. Specifically, the following devices will be evaluated to determine their training effectiveness and to elucidate generally effective computer-based instructional strategies:

- the Advanced Map Interpretation and Terrain Analysis Course (MITAC),

- the Modernized Cobra Preflight Inspection Trainer, and
- the Basic MITAC.

Research Approach

A comprehensive plan of research will be developed to maximize the generality of results from experiments with the Advanced MITAC, the Modernized Cobra Preflight Inspection Trainer, the Basic MITAC, and other prototype training devices that are developed by ARIARDA. The evaluation of each training device will be conducted as a separate project under this research area. Because the current projects are at different stages of development, a general research approach is presented. The status of the research is described separately for each project.

To evaluate the effectiveness of computer-based instructional strategies with the ARIARDA part-task training devices, the following tasks must be accomplished:

- design and conduct training effectiveness experiments for each prototype training device,
- use the experimental results to revise the courseware design, and
- continue training effectiveness experimentation until the maximum training benefit is realized.

Development of Part-Task Training Effectiveness Research Plans

Work Completed

During the current contract year, researchers at ARIARDA and Anacapa Sciences began the development of an integrative research plan. Three categories of training effectiveness research questions were identified. In the first category, the application of instructional principles, the broad research question is how can aviation skills be trained more effectively with a microcomputer than with the current training method. To answer this question, research will be conducted (a) to determine which aviation skills are required to perform missions, (b) to estimate the effectiveness of current institutional and unit training of these skills, and (c) to explore methods of computer-based instruction to improve the effectiveness and efficiency of this training.

The second category of questions is designed to determine the best performance taxonomy for conducting aviation part-task training research. Current military training research uses a variety of taxonomic approaches, including cognitive (e.g., skills, abilities, knowledge), behavioral (e.g., responses, response classes, response chains), and workload terms (e.g., tasks, functions, segments, missions). Research will be conducted to adapt or develop a taxonomy of aviation performance for use in the ARIARDA part-task training effectiveness evaluations.

For example, in July 1989, researchers at Anacapa Sciences proposed the development of a computer-based measurement procedure for map interpretation and terrain analysis skills and the empirical evaluation of the reliability, validity, and sensitivity of the procedure. The measurement procedure will serve as a criterion measure for training effectiveness research with the Advanced (and Basic) MITAC and as a diagnostic tool for operational training in map interpretation and terrain analysis.

The third category of questions addresses the conditional circumstances that affect aviation performance; that is, how do variations in external conditions affect the performance of aviation tasks. Preliminary research will outline the possible external conditions of aviation tasks and the dimensions along which these conditions typically vary. Formal research will investigate the effects of such variations on aviation performance and will develop strategies for incorporating effective variations into part-task training.

Work Projected

The broad research questions will be developed and refined into specific experimental and analytical objectives. For each objective, a plan of research will be drafted and submitted to ARIARDA.

Advanced MITAC Interactive Videodisc Training

The original format for the Advanced MITAC training program was a set of 16-mm film exercises in low-altitude geographic orientation (Kelley, 1979). The 16-mm films were converted to videodisc and the exercises were upgraded to an interactive computer-based training format (Miles & LaPointe, 1986b). During the current contract year, the Advanced MITAC software was converted from QuickBASIC to Turbo Pascal and modified to run on the Electronic Information Delivery System (EIDS). The Advanced MITAC for EIDS includes the standard courseware, a data collection program, and an instructor's review program. The interface permits the use of the EIDS keypad, keyboard, or lightpen.

In addition, a dual-screen version of the Advanced MITAC was developed. The native monitor of a host computer is used to display program instructions and to receive student input. A second monitor is used to display video from the videodisc player.

The current research and development effort with the Advanced MITAC focuses on (a) the effectiveness of the interactive videodisc method for training geographic orientation skills and (b) the evaluation of computer-based instructional strategies.

Work Completed

An experiment was conducted to evaluate the training effectiveness of the Advanced MITAC and to compare the effects of two methods of computer-based error remediation on inflight navigation performance. The results suggest that the Advanced MITAC is effective for teaching contour-level navigation skills to helicopter pilots. The results suggest that computer-generated error remediation is more effective than student-generated remediation, but further research is required to confirm this finding. A project report (Terrell, 1989a) and a plan for follow-on research (Terrell, 1988) were submitted to ARIARDA for review.

In February 1989, the dual-screen version of the Advanced MITAC was delivered to the NASA Ames Research Center at Moffett Field, California, for field testing in an emergency medical service flight navigation program. In July 1989, a set of Advanced MITAC vidediscs, software, and computer equipment was delivered to the Naval Air Station in Jacksonville, Florida, for field testing in the HS-1 Strike Rescue Course at Jacksonville.

Work Projected

The use of Advanced MITAC by the Naval Air Station and by the NASA Ames Research Center will continue to be monitored. If the ARIARDA part-task training effectiveness research plan requires the use of the Advanced MITAC, research will begin to develop a computer-based performance measurement procedure.

Modernized Cobra Preflight Inspection Trainer

The original format for this training program was an interactive videotape controlled by a microcomputer (Miles & LaPointe, 1986a). Preliminary research demonstrated the effectiveness of the experimental program by measuring performance on a preflight inspection multiple-choice test (Intano, 1988). However, incidental observations during this research suggested that the videotape format was less suitable than videodisc for computer-based training. The current research effort focuses on the development of a videodisc version of the training program and the evaluation of computer-based instructional strategies with the videodisc version of the trainer.

Work Completed

The Preflight Inspection Trainer videotape was converted to a videodisc format, and the courseware design and programming was initiated. Software was developed for dual-screen and single-screen viewing of the videodisc contents (see Terrell, 1989b). The single-screen version of the training program is currently being field tested in the flightline classrooms of the AH-1 Aviator Qualification Course at Fort Rucker, Alabama.

Work Projected

The field test of the Preflight Inspection Trainer will continue to be monitored. If required by the training effectiveness research plan, the Preflight Inspection Trainer will be used in research on computer-based instructional strategies.

Basic MITAC Interactive Videodisc Training

The Basic MITAC is currently being developed by Anacapa Sciences as a separate project (see Development of the Basic Map Interpretation and Terrain Analysis Course, pp. 99-103 of this report). Upon completion of that project, training effectiveness evaluations will be conducted under this research area. Specifically, the research will evaluate the effectiveness of the Basic MITAC in training general map interpretation and terrain analysis skills as a prerequisite for Advanced MITAC training.

If required by the training effectiveness research plan, experiments will be designed and conducted with the Basic MITAC to evaluate the effectiveness of various instructional strategies. The strategies will include different computer-based branching routines for remediating deficiencies, different methods for presenting drills and tutorials, full-motion versus still graphics, and visual versus audio narratives.

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ACCIDENT SCENARIO TRAINING

Mr. Joseph L. Zeller, Jr., Project Director

Background

Much of the training that Army aviators currently receive in both aircraft and flight simulators is designed to enhance safety, but little of the training is designed to reduce specific types of accidents. In most cases, deliberately creating accident-producing situations in actual flight is too risky even for aviators with substantial experience. There are several reasons that little flight simulator time has been devoted to accident reduction training. Early flight simulators were developed as instrument training devices and procedural trainers; they did not have the visual systems needed to create accident-producing situations. As more advanced simulators with both day and night visual capabilities have been developed, they have been used primarily to enhance operational and tactical skills. Finally, the personnel responsible for developing simulator training programs have not had adequate information about the situations in which aircraft accidents occur and the reasons for their occurrence.

In support of the Army Research Institute Aviation Research and Development Activity (ARIARDA) accident prevention research program, Anacapa Sciences was tasked to determine the viability of accident scenario training. Accident scenario training involves the use of a flight simulator or other training device to reenact, as accurately as possible, all the conditions and actions that have been shown to contribute to a frequently occurring type of accident. In principle, accident scenario training may serve to reduce accident likelihood in one or more of the following ways:

- teach aviators to recognize and avoid specific situations and conditions in which accident likelihood is high;
- teach aviators to recover the aircraft safely when accident-producing situations and conditions cannot be avoided; and
- teach aviators the specific search skills, perceptual judgment skills, and information processing skills that are required to avoid high hazard situations or to function safely in such situations.

Research Objectives

The general objectives of this project are to develop accident scenario training for a sample of accident types and to assess the cost-effectiveness of accident scenario training for the target accidents, considered individually and collectively. The specific technical objectives of the research project are as follows:

- identify types of helicopter accidents that are candidates for accident scenario training,
- validate the accident scenario training concept using a small sample of accident types (target accidents),
- develop training scenarios for the target accidents, and
- assess the training and cost effectiveness of accident scenario training aimed specifically at the target accidents.

Research Approach

The approach selected for meeting the research objectives involves three sequential tasks. The first task in assessing the feasibility and effectiveness of accident scenario training is to identify the types of helicopter accidents that occur. This task will be accomplished by conducting a systematic review of a large sample of accidents for which human error is known to be a causal factor. Accidents will be classified according to the circumstances surrounding the accident and the commonality of training necessary to eliminate the errors that caused or contributed to the accident.

The second task is to select a small sample of accident types (target accident types) to be investigated in validating the accident scenario training concept. The selection criteria will include the capability of conducting the training in available simulators, the importance (frequency and severity) of the accident type, and the representativeness of the set of accident types.

The third task is to develop training scenarios for the target accidents and to conduct research to assess their training and cost effectiveness in reducing the target accidents. The development of the training scenarios and the specification of training equipment requirements will be performed interactively to avoid developing scenarios that impose excessive equipment modifications.

Work Completed

Work on this project began in June 1989. Data for selected Class A-C helicopter accidents that occurred since fiscal year 1984 were requested from the U.S. Army Safety Center (USASC). The requested data are computer printouts of selected accident reporting forms that provide information such as the findings and recommendations, a narrative account of the investigation, data about the personnel involved (including their injuries if any), and the weather at the time of the accident. At the end of the current contract year, 367 computerized accident cases had been received from the USASC, including 73 cases in which night vision devices (NVDs) were in use. In addition, the USASC had approved a request for access to the computerized accident files (Army Safety Management Information System--ASMIS).

Written procedures for analyzing and classifying the accident cases and recording the results were developed and refined. The procedures describe the steps to be followed in reviewing each accident case file and the method for identifying the precipitating function failure (error or action that led directly to the accident), predisposing factors (errors or actions that increased the likelihood of the accident), and the phase of flight in which they occurred.

Approximately 150 accident case files, including all of the cases in which NVDs were in use, were reviewed by at least two different analysts. Accidents involving the Pilot Night Vision System (PNVS) were deleted from the sample because of the differences between the PNVS and the other night vision devices that use image intensifying tubes. In addition, accidents that occurred prior to flight and those that contained insufficient information for analysis were deleted from the review. The remaining reviews of the accident cases were compared and any differences in categorization by the two analysts were resolved. At the end of the contract year, each analyst had begun to develop an initial type classification of accidents that appear to be candidates for accident scenario training.

Work Projected

The remaining accident case files will be reviewed and the results compared and resolved. The initial type classification will be developed and refined as additional cases are analyzed. Target accident types will be selected on the basis of their suitability for scenario training and specific training requirements will be formulated for each target type. Two or three target accident types will be selected and used to validate the concept of accident scenario training. If the research findings indicate that the concept is valid, additional training scenarios will be developed and implemented.

TECHNICAL ADVISORY SERVICE: SUPPORT TO THE SPECIAL OPERATIONS AIRCRAFT PROGRAM MANAGER'S OFFICE

Mr. Carl R. Bierbaum, Technical Advisor

Background

The U.S. Army provides aviation support to the Special Operations Forces, a Department of Defense unit. The CH-47D and UH-60A aircraft are currently being used for aviation support, but the Army is developing special aircraft that will have additional capabilities. The Special Operations Aircraft (SOA) Program Manager's (PM) Office at the Army Aviation Systems Command has been tasked to develop the MH-60K and MH-47E aircraft. These aircraft will use the existing CH-47D and UH-60A airframes but will have a new, integrated cockpit. A standardized, integrated cockpit featuring four multifunction display (MFD) units will replace the present CH-47D and UH-60A instrument and gauge configurations.

The MH-60K and MH-47E aircraft are being designed to provide special operations aircraft that have increased capabilities and reduced crewmember workload. However, the high technology modifications being proposed for the MH-60K and MH-47E cockpits may increase workload by placing additional demands on the mental resources of the crewmembers. Researchers from the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) and Anacapa Sciences have developed a methodology for conducting mission/task analyses and predicting workload for emerging systems (Aldrich, Szabo, & Craddock, 1986). Additionally, Anacapa researchers, under contract to ARIARDA, developed a UH-60 workload prediction model (Bierbaum, Szabo, & Aldrich, 1989). Because of the experience gained from the conduct of these projects, Anacapa was tasked with providing technical advisory services to the MH-60K and MH-47E development programs.

Support Provided

The primary technical advisory support to the MH-60K and MH-47E development programs during the current contract year was to participate in the fifth Crew Station Working Group (CSWG) meeting for the Special Operations Aircraft at the Boeing Helicopter facilities in Philadelphia, Pennsylvania. The major areas of interest are summarized below.

At the meeting, the Anacapa technical advisor presented a briefing on the Task Analysis Workload (TAWL) methodology and the task analysis workload prediction models for the CH-47, UH-60, MH-47E and MH-60K. The Anacapa technical advisor also provided input for the following cockpit design items:

- procedure for uploading and storing navigational aid frequencies,
- auxiliary fuel tank fuel level sensors,
- types of pilot and copilot doors for the MH-60K,
- switches and procedures to zero the classified avionics and mission processors, and
- switches to increase the interphone control system (ICS) panel from 5 to 7 positions.

Support Projected

No further support is projected at this time. However, Anacapa personnel will resume technical advisory support to the SOA PM if tasked by ARIARDA.

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TECHNICAL ADVISORY SERVICE: SUPPORT TO OPERATOR WORKLOAD (OWL) RESEARCH

Dr. David B. Hamilton and Mr. Carl R. Bierbaum,
Technical Advisors

Background

In 1986, the Army Research Institute (ARI) awarded a multi-year contract (MDA903-86-C-0384) for research in "Controlling Operator Workload in Army Systems Design and Evaluation" to Analytics, Inc., of Willow Grove, Pennsylvania. The contract was awarded because of the recognized need for systematic and validated methods to estimate workload or to isolate its causes during system design. Specifically, the research was designed to accomplish the following objectives:

- assess the existing operator workload measures for their utility in system design and evaluation,
- evaluate operator workload in three representative Army systems,
- develop guidelines for choosing the most appropriate workload assessment techniques for varying conditions, and
- prepare a pamphlet and handbooks to guide personnel in assessing workload in emerging Army systems.

To meet the objectives, operator workload was examined in the AQUILA remotely piloted vehicle and the Forward Area Air Defense Line of Sight-Forward (Heavy) system. The research objectives required the third system to be an aviation system. After a false start with the Airborne Target Handover System, the UH-60 Blackhawk was chosen as the representative aviation system.

A comprehensive review and evaluation of workload methodologies was conducted. The research concentrated on several analytic methods of workload prediction and the comparison of subjective workload measures in the three systems. After reviewing several analytic methods, the ARIARDA/Anacapa Sciences task analysis/workload (TAWL) methodology and the TAWL Operator Simulation System (TOSS) were selected for evaluation because they had previously been used to develop the UH-60 workload prediction model (Bierbaum, Szabo, & Aldrich, 1989). At the request of Analytics, ARIARDA tasked Anacapa to support the research to assess the operator workload in the UH-60 aircraft.

Research Approach

The Analytics research plan was divided into three phases. In phase one, subjective measures of workload were collected during simulated flight missions in the UH-60 flight simulator at Fort Rucker, Alabama. In phase two, a TAWL workload prediction model was developed to predict the workload of the operators during the simulated mission scenario. In phase three, the subjective measures collected in phase one were compared with the predictions of the model obtained in phase two.

Support Provided

Anacapa personnel provided the following support to the operator workload research:

- attended meetings and assisted in planning the UH-60 simulator research (phase one),
- produced a workload prediction model for the UH-60 flight mission (thus completing phase two in its entirety), and
- assisted in the interpretation of the results found during the comparison of the simulator data and the model's predictions.

The majority of the Anacapa support was used to develop the Analytics/UH-60 workload prediction model. During the UH-60 flight simulator phase, Analytics researchers collected subjective estimates of operator workload in 12 mission segments. Because each of the Analytics segments contained several Anacapa UH-60 defined segments, Anacapa personnel programmed and tested new decision rules to model the simulated segments. The model data and the TOSS software system was delivered to Analytics in April 1989.

Subsequently, Analytics personnel executed the model and summed the model's predictions over executions, workload components, and time to produce single workload estimates for 6 of the 12 mission segments. They scaled the estimates to the range of the subjective measures (1-100) and correlated the average operator workload for several crews in the simulator with the output of the workload prediction model. Generally, the correlations between the subjective measures and predicted workload were high ($\underline{r}$ = .62 to .95). They concluded that the TAWL methodology has substantial potential as a workload estimation technique that could be applied before system development. The results of the research are reported in Iavecchia, Linton, Bittner, and Byers (1989).

Support Projected

No further support is projected for the Analytics Operator Workload research.

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TECHNICAL ADVISORY SERVICE: SOFTWARE DEVELOPMENT FOR FLIGHTLINE RESEARCH SYSTEMS

Ms. Stephanie Noland and Ms. Laura Fulford,
Technical Advisors

Background

Scheduling of aviation training resources at the U.S. Army Aviation Center (USAAVNC), Fort Rucker, Alabama, is a time-consuming and potentially costly activity. For example, the 1-14th Battalion coordinates and schedules requests for aircraft, stagefields, refueling, bus and air transportation, ammunition, and remote landing site lighting. The scheduling of these resources is accomplished manually; a mistaken order of only one extra aircraft can cost hundreds of dollars.

The resources required for all classes are scheduled in 5-week written projections, 1-week updated written projections, and two daily squaring sessions conducted by telephone. The Army currently uses Form 325 for this scheduling.

Research Objective

The objective of this project is to develop a computer hardware and software system that will automate the scheduling of aviation training resources. An efficient, automated system will increase speed and accuracy and reduce the costs of scheduling errors. In January 1988, the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA) assigned the development of the automated system to another of their contractors. In July 1988, ARIARDA tasked Anacapa Sciences to provide software development support to the project.

Research Approach

The 1-14th Battalion at the USAAVNC was chosen as the prototype training organization for this project because it has the most complex resource requirements. The 1-14th Battalion has six training companies (A - F); each company manages between two and five different courses. As many as seven classes may be in residence in a company at any given time.

A MicroVax II (VAX) microcomputer was chosen as the central processor for the scheduling system. The six training companies and the battalion staff were provided with

Zenith 248 personal computers to use in logging onto the VAX and for accessing the resident programs and data. The system design provides customized programs that enable each company to build, edit, update, and print data about its classes. At the battalion level, computer programs gather and organize the information from the six on-line company class files into battalion reports. The battalion reports include aircraft, ammunition, stagefield, refueling, bus transportation, and air transportation requests for each company. A battalion program gathers the twice daily company change requests into a transaction log to square with the brigade schedules.

Support Provided

During the current contract year, Anacapa continued to provide technical assistance in developing the Flightline Research System (FLRS) software. In October 1988, the Anacapa technical advisor was assigned the role of systems manager for the MicroVax II hardware system and was responsible for completing the development of the FLRS software. She was also responsible for training 1-14th personnel and testing A Company and Battalion software.

Two new battalion programs were developed and tested: one program compiles Artillery Support Requests from all companies and the second program compiles Cover Flight Requests. The new programs were linked to the battalion menu system and all company course templates were modified to include requests for these resources.

In November 1988, the Anacapa technical advisor developed the "ARIARDA FLRS Company Level Users Guide" and the "ARIARDA FLRS Battalion S3 Users Guide." The guides explain in detail how to use each of the company and battalion programs. Both guides were reviewed by the ARIARDA project director and by the Battalion Operations Officer. Copies of the guides were distributed to Battalion, A Company, and F Company operations personnel.

During December 1988, the company and battalion programs were modified so that the battalion programs accessed data from the second week of the company class files. This allowed the battalion to obtain weekly projections on the preceding Tuesday rather than on Friday. All company test files were modified accordingly, and tests were run successfully.

The Anacapa technical advisor trained F Company operations personnel to use all of the company programs. They used the programs to build their classes and to submit their 5-week resource predictions. They did not use the company programs for daily squaring.

Also during December 1988, the Battalion Operations Officer requested modifications to the scheduling program and templates so that 18 rather than 12 weeks could be scheduled. This revision was necessary to accommodate the 80-training-day IERW course. In January 1989, the modified software was tested and benchmarked.

As a result of the tests, the technical advisor determined that the software system would be unable to meet the deadlines for squaring the daily schedules. The technical advisor attempted to convert the VAX-resident class building programs to run on the Zenith 248 computer using the spreadsheet 20/20 software. However, only 3 weeks of data could be installed because of the memory limitation of 640K. Because of these problems, ARIARDA decided to cancel the A Company and Battalion test and to cease work on the Form 325 software.

Support Projected

No additional support is projected for the Flightline Research System.

TECHNICAL ADVISORY SERVICE: PROGRAMMING SUPPORT TO THE THREAT PART-TASK TRAINER

Mr. Gary W. Coker, Technical Advisor

Background

Force modernization has resulted in a proliferation of complex systems in the Army. To train personnel on these systems, the Army has developed a cost-effective, standardized method for delivering doctrinal, instructional, and technical materials. This method is called the Electronic Information Delivery System (EIDS), an integrated computer-videodisc interactive system. A program called ASSIST is the standard courseware authoring system for use on EIDS.

As part of an ongoing research program in part-task training effectiveness, the Army Research Institute Aviation Research and Development Activity (ARIARDA) has developed an interactive videodisc (IVD) system to provide Soviet threat identification training to soldiers. The THREAT system comprises a PC-AT compatible computer, a standard videodisc player, and a separate video-graphics overlay controller. The courseware was authored using the Computer-Based Memorization System (CBMS).

Need

The THREAT identification trainer developed by ARIARDA uses a non-EIDS-compatible interactive video system. Because EIDS is the Army-wide standard, conversion of the THREAT courseware to EIDS compatibility will increase its utility as a training device and its potential as a training research instrument. Consequently, ARIARDA directed Anacapa Sciences to modify the THREAT courseware to use the EIDS-ASSIST system.

Project Objectives

The primary function of this technical advisory service is to provide EIDS programming support to ARIARDA part-task training effectiveness researchers. The specific objectives are (a) to review the EIDS-ASSIST technical literature and (b) to produce a prototype training program using the THREAT videodisc, ASSIST, and EIDS. The prototype program will emphasize the identification and discrimination of the Soviet mapping symbols on the THREAT videodisc.

Support Provided

After obtaining the EIDS system documentation, the Anacapa technical advisor became familiar with the EIDS hardware: the system unit, RGB monitor, keyboard, lightpen, joystick, a hard disk drive, and keypad. Then the Advanced MITAC IVD trainer was ported to EIDS from its original delivery system to provide familiarization with the EIDS computer-videodisc communication interface, input devices, and video-graphics overlay controller.

All available ASSIST documentation and software were assembled and studied. Preliminary THREAT courseware design began using sample ASSIST code as a model. The courseware was developed to train the names and appearance of Soviet mapping symbols using the ASSIST authoring system. The videodisc from the THREAT trainer was used to provide the video imagery for the symbols. Computer graphics for presenting the introductory and instructional material were also developed for use in the courseware.

After completing the ASSIST database, the program was tested, revised, and debugged. The feasibility of various options in courseware design, such as use of computer-generated graphics instead of videodisc imagery, was also evaluated. All options identified by ARIARDA were feasible using the EIDS system.

Support Projected

All work assigned to Anacapa Sciences by the original ARIARDA tasking has been completed. If additional work is required, Anacapa personnel will continue to support THREAT-related programming of the EIDS computer.